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ANNUAL REPORT OF THE
BOARD OF REGENTS OF
THE SMITHSONIAN
INSTITUTION

SHOWING THE
OPERATIONS, EXPENDITURES, AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDING JUNE 30

1921



(Publication 2675)

A164

WASHINGTON
GOVERNMENT PRINTING OFFICE

1922

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LETTER
FROM THE
SECRETARY OF THE SMITHSONIAN INSTITUTION

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE
INSTITUTION FOR THE YEAR ENDING JUNE 30, 1921.

SMITHSONIAN INSTITUTION,

Washington, April 18, 1922.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1921. I have the honor to be,

Very respectfully, your obedient servant,

CHARLES D. WALCOTT,

Secretary.

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ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN
INSTITUTION FOR THE YEAR ENDING JUNE 30, 1921.

SUBJECTS.

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1921, with statistics of exchanges, etc.

2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1921.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1921.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1921.

THE SMITHSONIAN INSTITUTION.

June 30, 1921.

Presiding officer ex officio.—WARREN G. HARDING, President of the United States.
Chancellor.—CALVIN COOLIDGE, Vice President of the United States.

Members of the Institution:

WARREN G. HARDING, President of the United States.
CALVIN COOLIDGE, Vice President of the United States.
WILLIAM HOWARD TAFT, Chief Justice of the United States.
CHARLES EVANS HUGHES, Secretary of State.
ANDREW W. MELLON, Secretary of the Treasury.
JOHN WINGVIE WEEKS, Secretary of War.
HARRY M. DAUGHERTY, Attorney General.
WILLIAM H. HAYS, Postmaster General.
EDWIN DENBY, Secretary of the Navy.
ALBERT BACON FALL, Secretary of the Interior.
HENRY CANTWELL WALLACE, Secretary of Agriculture.
HERBERT CLARK HOOVER, Secretary of Commerce.
JAMES JOHN DAVIS, Secretary of Labor.

Regents of the Institution:

CALVIN COOLIDGE, Vice President of the United States, Chancellor.
WILLIAM HOWARD TAFT, Chief Justice of the United States.
HENRY CABOT LODGE, Member of the Senate.
A. OWSELY STANLEY, Member of the Senate.
MEDILL McCORMICK, Member of the Senate.
LEMUEL P. PADGETT, Member of the House of Representatives.
FRANK L. GREENE, Member of the House of Representatives.
JOHN A. ELSTON, Member of the House of Representatives.
ALEXANDER GRAHAM BELL, citizen of Washington, D. C.
GEORGE GRAY, citizen of Delaware.
CHARLES F. CHOATE, Jr., citizen of Massachusetts.
JOHN B. HENDERSON, citizen of Washington, D. C.
HENRY WHITE, citizen of Maryland.
ROBERT S. BROOKINGS, citizen of Missouri.

Executive committee.—GEORGE GRAY, ALEXANDER GRAHAM BELL, HENRY WHITE,
Secretary of the Institution.—CHARLES D. WALCOTT.

Assistant Secretary.—C. G. ABER.

Chief clerk.—HARRY W. DORSEY.

Accounting and disbursing agent.—W. I. ADAMS.

Editor.—W. P. TRUE.

Assistant librarian.—PAUL BROCKGUT.

Property clerk.—J. H. HILL.

THE NATIONAL MUSEUM.

Keeper ex officio.—CHARLES D. WALCOTT, Secretary of the Smithsonian Institution.

Administrative assistant to the Secretary, in charge.—W. DE C. RAYENEL.

Head curators.—WALTER HOUGH (Acting), LEONHARD STEJNEGER, G. P. MERRILL.

Curators.—PAUL BARISCH, R. S. BASSLER, T. T. BELOIE, AUSTIN H. CLARK, F. W. CLARKE, F. V. COVILLE, W. H. DALL, WALTER HOUGH, L. O. HOWARD, ALES HRDLÍČKA, NELL M. JUDD, FREDERICK L. LEWTON, GEORGE P. MERRILL, GERRIT S. MILLER, JR., CARL W. MITMAN, ROBERT RIDGWAY, WALDO L. SCHMITT, LEONHARD STEJNEGER.

Associate curators.—J. M. ALDRICH, C. W. GILMORE, W. R. MAXON, CHARLES W. RICHMOND, J. N. ROSE, DAVID WHITE.

Chief of correspondence and documents.—H. S. BRYANT.

Disbursing agent.—W. I. ADAMS.

Superintendent of buildings and labor.—J. S. GODSMITH.

Editor.—MARCUS BENJAMIN.

Assistant librarian.—N. P. SCUDDER.

Photographer.—ARTHUR J. OLMSTED.

Property clerk.—W. A. KNOWLES.

Engineer.—C. R. DENMARK.

Shipper.—I. E. PERRY.

NATIONAL GALLERY OF ART.

Director.—WILLIAM H. HOLMES.

BUREAU OF AMERICAN ETHNOLOGY.

Chief.—J. WALTER FEWKES.

Ethnologists.—JOHN P. HARRINGTON, J. N. B. HEWITT, FRANCIS LA FLESCHÉ, TRUMAN MICHELSON, JAMES MOONEY, JOHN R. SWANTON.

Editor.—STANLEY SEARIS.

Librarian.—ELLA LEARY.

Illustrator.—DE LANCEY GILL.

INTERNATIONAL EXCHANGES.

Chief clerk.—C. W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK.

Superintendent.—NED HOLLISTER.

Assistant Superintendent.—A. B. BAKER.

ASTROPHYSICAL OBSERVATORY.

Director.—C. G. ABERT.

Aid.—F. E. FOWLE, JR.

Assistant.—L. B. ALDRICH.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

Assistant in charge.—LEONARD C. GINSILL.

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

CHARLES D. WALCOTT,

FOR THE YEAR ENDING JUNE 30, 1921.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to submit herewith the annual report on the activities and condition of the Smithsonian Institution and its branches during the year ending June 30, 1921. The affairs of the Institution proper are reviewed on the first 24 pages of this report, while more detailed accounts of the year's work of the various branches of the institution are given in the appendices hereto. These include reports on the United States National Museum, the Bureau of American Ethnology, the International Exchange Service, the National Zoological Park, the Astrophysical Observatory, the Smithsonian Library, the United States Regional Bureau of the International Catalogue of Scientific Literature, the National Gallery of Art, the Freer Gallery of Art, and the publications of the Institution and its branches.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS.

The affairs of the Institution are administered by a Board of Regents, whose membership consists of "the Vice President, the Chief Justice, three Members of the Senate, and three Members of the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of them of the same State." One of the Regents is elected chancellor by the board: in the past the selection has fallen on either the Vice President or the Chief Justice; and a suitable person is chosen by them as secretary of the Institution, who is also secretary of the Board of Regents and the executive officer directly in charge of the Institution's activities.

In regard to the personnel of the board, it becomes my sad duty to record the death, on May 19, 1921, of its chancellor, Edward Douglass White, Chief Justice of the United States. Resolutions in memory of Chancellor White were adopted by the Regents at a special meeting held May 27, 1921, when the Hon. Calvin Coolidge, Vice President of the United States, was elected chancellor of the Institution.

The only other change in the personnel of the board was the appointment of the Hon. A. Owsley Stanley, Senator from Kentucky, as a Regent on January 5, 1921, to succeed Senator Charles S. Thomas. The roll of Regents at the close of the fiscal year was as follows: Calvin Coolidge, Vice President of the United States, chancellor; Henry Cabot Lodge, Member of the Senate; A. Owsley Stanley, Member of the Senate; Medill McCormick, Member of the Senate; Lenuel P. Padgett, Member of the House of Representatives; Frank L. Greene, Member of the House of Representatives; John A. Elston, Member of the House of Representatives; Alexander Graham Bell, citizen of Washington, D. C.; George Gray, citizen of Delaware; Charles F. Choate, jr., citizen of Massachusetts; John B. Henderson, citizen of Washington, D. C.; Henry White, citizen of Maryland; and Robert S. Brookings, citizen of Missouri.

The board held its annual meeting on December 9, 1920. The proceedings of that meeting, as well as the annual financial report of the executive committee, have been printed as usual for the use of the Regents, while such important matters acted upon as are of public interest are reviewed under appropriate heads in the present report of the secretary. A detailed statement of disbursements from the Government appropriations under the direction of the Institution for the maintenance of the National Museum, the National Zoological Park, and other branches will be submitted to Congress by the secretary in the usual manner in accordance with the law.

GENERAL CONSIDERATIONS.

The act establishing the Smithsonian Institution in 1846 included in its functions the promotion of art as well as science. Heretofore this phase of the Institution's activities has remained somewhat in abeyance owing to the lack of means to further it, but within the last few years a tremendous impetus has been given the art feature. At the beginning of the past fiscal year the National Gallery of Art, formerly administered as a part of the National Museum, became a separate unit under the Smithsonian Institution, and Congress provided a small appropriation for its maintenance. This important step will do much toward the development of Washington as an art center, and will undoubtedly bring much desirable material to the national collections, already valued in money at several million dollars. The Freer Gallery of Art, a unit of the National Gallery, was brought practically to completion during the year, and work is going forward on the installation of the Freer collection. This beautiful building and the unexcelled collection of American and oriental art which it contains are, as noted in previous reports, the gift to the Nation, through the Smithsonian Institution, of the late Mr. Charles L. Freer, of Detroit.

It is an unpleasant duty to here record again the pressing need of the Institution for a larger endowment. Although several generous contributions have been received since the founding of the Institution, few material additions to its endowed funds have ever been made. Despite the greatly enlarged field of its scientific activities, despite the ever-increasing demands for scientific information from individuals throughout the country, its income has remained substantially the same. Almost daily the Institution is forced to forego opportunities for valuable explorations and scientific researches on account of lack of means, and it is hoped that some far-sighted benefactor, recognizing the advantageous position and unexcelled facilities of the Smithsonian Institution for carrying on valuable researches in every branch of science, will provide an endowment sufficient to enable it to carry on this work in the "increase and diffusion of knowledge among men."

Bequests.—As noted in a previous report, an important bequest was made to the Institution under the terms of the will of Mrs. Virginia Purdy Bacon, of New York, probated April 14, 1919, which will do much toward extending our knowledge of the fauna of the world.

That portion of Mrs. Bacon's will relating to the Institution reads as follows:

(f) To Smithsonian Institute the sum of fifty thousand dollars (\$50,000), to be used in establishing a traveling scholarship, to be called the Walter Rath-

bone Bacon scholarship for the study of the fauna of countries other than the United States of America; the incumbents to be designated by said Institute under such regulations as it may from time to time prescribe and to hold such scholarship not less than two years, and while holding such scholarship to conduct for said Institute investigations in the fauna of other countries under the direction of said Institute.

During the year the Institution received from the executors of Mrs. Bacon's estate securities amounting to \$45,000 on account of the total \$50,000. At the close of the year sufficient income from this amount had not been received to enable the first scholarship to be established, but it is planned to inaugurate the project during the coming year.

Miss Caroline Henry, daughter of Joseph Henry, first secretary of the Institution, died November 10, 1920. Under the terms of her will the Institution is named as the ultimate beneficiary, the entire estate reverting to it after the death of the last life beneficiary, as a memorial to her father and mother. Miss Henry also bequeathed to the Institution the sum of \$1,000 and certain articles of furniture; to the National Museum a set of china presented to Joseph Henry by the first Japanese minister; and to the National Gallery of Art an oil portrait by Kneller.

FINANCES.

The investments of the Institution are as follows:

Deposited in the Treasury of the United States under authority
of Congress..... \$1,000,000

CONSOLIDATED FUND.

These securities are carried at cost and represent the investments made by the Institution, or gifts transferred to the Institution by the donors. The total of this fund now amounts to \$157,562.05, namely:

Province of Manitoba 5 per cent gold debentures, due in 1922.....	\$2,000
West Shore Railroad Co. guaranteed 4 per cent first mortgage bonds, due in 1931.....	42,000
Cleveland Electric Illuminating Co. first mortgage 5 per cent gold bonds, due in 1939.....	10,000
Atchison, Topeka & Santa Fe Railroad Co. 4 per cent general mortgage bonds, due in 1935, gift.....	2,000
Chesapeake & Ohio Railroad Co. 5 per cent first consolidated mortgage bonds, due in 1939, gift.....	2,000
Baltimore & Ohio Railroad Co. 5 per cent refunding general mortgage bonds, due in 1935, gift.....	5,000
P. Lorillard Co. 7 per cent gold bonds, due in 1944, gift.....	6,000
Lizaitt & Myers Tobacco Co. 7 per cent gold bonds, due in 1944, gift.....	6,000
City of Youngstown, Ohio, 6 per cent municipal bonds, due in 1928.....	3,000
Brooklyn Rapid Transit Co. 5 per cent secured gold notes, due in 1918.....	3,500
Northern Pacific--Great Northern joint convertible 6½ per cent gold bonds, due in 1936.....	41,500

United States first Liberty loan.....	200
United States second Liberty loan.....	100
United States third Liberty loan.....	10,150
United States fourth Liberty loan.....	50
United States Victory loan.....	6,550
United States war-savings stamps, series of 1918.....	100
Atchison, Topeka & Santa Fe Railroad Co. 5 per cent preferred stock, gift..... shares.....	125
American Smelting & Refining Co. 7 per cent preferred stock, gift.....do.....	60
Baltimore & Ohio Railroad Co. 4 per cent preferred stock, gift.....do.....	125

The \$3,500 par value of the 5 per cent gold notes of the Brooklyn Rapid Transit Co. are held in the hands of receivers pending re-organization. No plan, however, has yet been adopted.

The sum invested for each specific fund and the manner in which held is described as follows:

Fund.	United States Treasury.	Consolidated fund.	Total.
Smithson fund.....	\$727,640 00	\$1,468 74	\$729,108.74
Habel fund.....	500.00		500.00
Hodgkins general fund.....	116,000.00	37,275.00	153,275.00
Hodgkins specific fund.....	100,000.00		100,000.00
Rhees fund.....	590.00	156.00	746.00
Avery fund.....	14,000.00	18,439.80	32,439.80
Addison T. Reid fund.....	11,000.00	2,850.00	13,850.00
Lucy T. and George W. Poore fund.....	26,670.00	8,660.00	35,330.00
George K. Sanford fund.....	1,100.00	204.00	1,304.00
Chamberlain fund.....		35,000.00	35,000.00
Bruce Hughes fund.....		8,741.93	8,741.93
Lucy H. Baird fund.....		1,166.58	1,166.58
Virginia Purdy Bacon fund.....		45,000.00	45,000.00
Hamilton fund.....	2,500.00	500.00	3,000.00
Total	1,000,000.00	157,562.05	1,157,562.05

To Mr. H. B. Swales, custodian, section of birds' eggs, the Institution is indebted for an additional gift of \$100 for the purchase of specimens, making a total contribution of \$700 since January, 1919.

Some of the unimproved land near Lowell, Mass., has been sold, and the sum of \$226.42 was realized therefrom and invested for account of the Lucy T. and George W. Poore fund.

Dr. William L. Abbott has contributed \$2,000 during the year to the maintenance of a field party, the purpose of which is to procure archeological and natural history specimens in Australia. This expedition followed those to Borneo and Celebes and has now continued for two and a half years.

The Institution has received for specific activities further valuable contributions from Mr. John A. Roebling, amounting to \$15,200.

In partial settlement of the Charles L. Freer bequest the Institution received, in October, 1920, 3,919 shares of the stock of Parke. Davis & Co. (Inc.), and in March, 1921, 10,000 shares, making a total of 13,919 shares. The dividends are required to be expended in accordance with the terms prescribed by the testator. The total amount received by the Institution from this source since the transfer of these shares was \$25,970.75, and the sum of \$15,026.01 has been expended.

Current funds not immediately required for expenditure are, when conditions will permit, deposited on time in local trust companies and draw 3 per cent per annum. The interest received in this manner during the fiscal year 1921 amounted to \$1,066.67.

The income during the year consisted of interest on permanent investments and other revenues for current expenses. \$61,576.32: receipts from bequests and for specific purposes. \$110,740.47; which, with cash subject to check on July 1, 1920, amounting to \$13,304.34, constituted a total of \$185,621.13.

The disbursements described in the annual report of the executive committee were classed as follows: General objects of the Institution, \$66,202.39; investments and expenditures for specific purposes. \$93,816.33; temporary advances for field expenses, etc., \$9,373.07, leaving \$5,000 deposited on time and \$11,229.34 subject to check.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1921:

International Exchanges.....	\$50,000
American Ethnology.....	44,000
International Catalogue of Scientific Literature	7,500
Astrophysical Observatory.....	13,000
National Museum:	
Furniture and fixtures.....	20,000
Heating and lighting.....	74,000
Preservation of collections.....	312,620
Building repairs.....	10,000
Books.....	2,000
Postage.....	500
National Gallery of Art.....	15,000
National Zoological Park:	
Maintenance.....	125,000
Purchase of additional land.....	80,000
Total.....	753,620

In addition to the above, there was appropriated for printing and binding \$123,123.69 to cover the cost of printing and binding the Smithsonian annual report and reports and miscellaneous printing for the Government branches of the Institution. This includes the

usual annual appropriation for printing and binding and the additional amount appropriated by Congress for printing delayed by war work.

RESEARCHES AND EXPLORATIONS.

An important phase of the Institution's work in the "increase and diffusion of knowledge among men" is the scientific exploration of little-known parts of the earth, as well as the extending of existing knowledge concerning better-known regions through field-work. Although the Institution's funds for this purpose are extremely limited, it is often able to cooperate advantageously with other establishments in putting expeditions in the field. The results of these numerous explorations in every quarter of the globe have not only advanced scientific knowledge, but have greatly enriched the collections in the United States National Museum in biology, geology, and anthropology.

A number of the expeditions sent out during the past year are described in the appendices to this report, and others are here reviewed briefly to indicate the character of the Institution's work in this direction.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES.

Your secretary continued his geological field-work in the Canadian Rockies with two main objects in view. (1) the determination of the character and extent of the great interval of nondeposition of sedimentary rock-forming material along the Front Range of the Rocky Mountains west of Calgary, Alberta; (2) the clearing up of the relations of the summit and base of the great Glacier Lake section of 1919 to the geological formation above and below. Work was begun early in July along the Ghost River northeast of Banff, Alberta.

The solution of the two problems attacked may be briefly described as follows:

The Rocky Mountain front is formed of masses of evenly bedded limestone that have been pushed eastward over the softer rocks of the Cretaceous plains-forming rocks. This overthrust is many miles in extent and occurred long before the Devils Gap, Ghost River Gap, and other openings were cut through the cliffs by running water and rivers of ice. Great headlands and high buttes have been formed by the silent forces of water and frost, many of which stand out against the western sky as seen from the distant foothills and plains.

It was among these cliffs that we found that the first great cliff was of lower Middle Cambrian age, and that resting on its upper

surface there were 285 feet (86 meters) of a yellowish weathering magnesian limestone, named the Ghost River formation, which represents the great interval between the Cambrian below and the Devonian above. Sixty miles to the west, over 4 miles in thickness of limestone, shales and sandstones occur in the break in sedimentation of Ghost River cliffs.

Returning to Bow Valley, the party left the Canadian Pacific Railroad at Lake Louise and went north over Pipestone Pass to the Siffleur River, which is tributary to the Saskatchewan. In the northward facing cliffs, 25 miles (40 kilometers) east of the Glacier Lake section of 1919, and 40 miles (64 kilometers) north of Lake Louise, a geological section was studied that tied in the base of the Glacier Lake section of 1919 with the Middle and Lower Cambrian formations. Returning up the canyon valley of the Siffleur River to the wide upper valley of the Clearwater River, a most perfectly exposed series of limestones, shales, and sandstones of Upper Cambrian and later formations was found, which cleared up the relations of the upper portion of the Glacier Lake section to the Ordovician above.

The work was considerably handicapped by forest fires in July and August and by unusually stormy weather in September.

PALEONTOLOGICAL FIELD-WORK.

Dr. R. S. Bassler, curator of paleontology, National Museum, succeeded during the year in securing for the Museum's collections two much-desired specimens, one a large well-preserved fossil elephant skull formerly exhibited in Cincinnati, the other a highly fossiliferous limestone slab of Silurian age quarried out by him near Oxford, Ohio. Such a slab has long been desired to show the advancement in life from the primitive Cambrian forms, represented in the large Cambrian sea-beach sandstone exhibit, to the higher and more complex species of succeeding geological periods. Notwithstanding the numerous occurrences of fossiliferous limestone of Ordovician and Silurian age, it was not until the past year that a layer affording slabs of suitable size and sufficient perfection of preservation was brought to the attention of the Museum. Numerous large blocks of stone had to be removed before the real task of quarrying the desired slab was begun. The work was successfully accomplished with the generous assistance of Dr. W. H. Shideler, professor of geology at Miami University, Oxford, Ohio, who first located the specimen, and before the close of the year this valuable educational exhibit was installed in the hall of invertebrate paleontology.

At the conclusion of this work Doctor Bassler proceeded to Chicago for the purpose of securing casts of type specimens of fossils in the

collections of the Walker Museum, University of Chicago. Regarding this work, Doctor Bassler says:

The paleontological collection of the National Museum, which includes the celebrated Walcott, Ulrich, Springer, Harris, Nettelroth, and Rominger collections, is especially rich in type specimens of early Paleozoic fossils, but nevertheless the Walker Museum possesses many unique types not represented at all in Washington. Permission to prepare casts of these and thus advance our study series toward the completeness which the National collections should attain was generously granted by Dr. Stuart Weller, director of the Walker Museum. In two weeks' time I was enabled to finish casting all of the Ordovician and Silurian types, leaving the remaining Paleozoic species for a future trip. The work was done quickly by using the modeling compound (plasticene) to make the mold from which the cast is prepared.

THE SMITHSONIAN AFRICAN EXPEDITION.

The Smithsonian African expedition, in conjunction with the Universal Film Manufacturing Co., which was described in my last report, concluded its work shortly after the beginning of the fiscal year, and somewhat later the collections made by Mr. H. C. Raven, the Institution's representative on the expedition, were received by the National Museum. Among the more important material may be mentioned 697 mammals (including 272 specimens from South Africa, a region hitherto very imperfectly represented in the Museum's collections; 152 from Lake Tanganyika; and the chimpanzee of Uganda), 575 birds, 206 reptiles, and 193 fishes. Although not numerically large, these collections are of unusual interest on account of the manner in which they supplement those obtained by other expeditions to Africa in which the Smithsonian Institution has been interested.

Dr. H. L. Shantz, of the United States Department of Agriculture, also accompanied the expedition with the objects in view of securing live plants of agricultural value for introduction into the United States, of studying the agricultural methods of both natives and Europeans, and of collecting plants for the National Herbarium of the United States National Museum. Over 1,000 botanical specimens were secured for the Museum, and first-hand observations were made of the methods of agriculture pursued by African tribes as well as the Europeans. About 1,600 plants were collected for growth as agricultural plants in this country, the more important being forage plants, nut plants, fruits, and vegetables.

AUSTRALIAN EXPEDITION.

Through the generosity of Dr. W. L. Abbott, Mr. Charles M. Hoy continued his work of collecting for the Museum specimens of the very interesting fauna of Australia. The results of this expedition are of especial value for two reasons: First, the Australian fauna

has heretofore been but scantily represented in the Museum, and, second, the remarkable fauna of that continent is rapidly being exterminated through various causes. During the year two shipments were received from Mr. Hoy containing a total of 440 mammals well prepared, several of which were hitherto unrepresented in the collection, together with series of skeletal and embryological material; 570 bird skins, with 24 additional examples in alcohol, and smaller collections of reptiles, amphibians, insects, marine specimens, etc.

MALACOLOGICAL FIELD-WORK IN CALIFORNIA AND THE HAWAIIAN ISLANDS.

On the way to the First Pan-Pacific Scientific Congress, held in Honolulu, August 2 to 20, 1920, Dr. Paul Bartsch, curator of mollusks, United States National Museum, spent one day on shipworm investigation at Mare Island, Calif. A tug was placed at his disposal by the commandant of the station in order to make every minute of the brief visit count, and the investigation resulted in the discovery that the mollusk which caused damage to the extent of some \$25,000,000 last year is a new species of *Teredo*, which Dr. Bartsch named *Teredo beachi*, in honor of the commandant of Mare Island.

In the Hawaiian Islands, collections of mollusks were made at several localities, and dredgings were made in Pearl Harbor, where the commandant placed a dredge at the disposal of Doctor Bartsch and Mr. John B. Henderson. Here also a new species of shipworm was discovered, which was named *Teredo parksi*, in honor of Admiral Parks.

An interesting observation made at the southeast point of Hanouma Bay was the finding of an existing marine flora and fauna at a considerable elevation above the level of the sea. Regarding this occurrence, Doctor Bartsch says:

This flora and fauna consist of algae, quite a number of species of mollusks, crustaceans, echinoderms, and other marine organisms, which occupy pools and puddles kept ever moist and supplied with fresh water by the spray from the breaking surf, which incessantly pounds that shore. I consider this an important observation, since the occurrence of fossiliferous laminae bearing marine organisms between sheets of lava has been held to indicate that they were deposited at or below sea level, and their occurrence above this has been held as evidence of elevation. We have here an instance which indicates that this is not necessarily the case, for such a lamina would be produced if a new outpouring of lava were to cover up the place mentioned.

BOTANICAL RESEARCHES IN THE ORIENT.

Dr. A. S. Hitchcock, custodian, section of grasses, United States National Museum, left Washington the last of April for several months' botanical work in the Orient under the auspices of the

United States Department of Agriculture. This journey was undertaken with two main objects in view: (1) To study the grasses of the Philippine Islands in response to a request from the director of the Philippine Bureau of Science (Dr. E. D. Merrill) to prepare the manuscript on the grasses for a flora of the Philippine Islands; (2) to study the native and cultivated bamboos of the Philippines, Japan, and China with special reference (1) to their introduction into the United States and (2) to the publication of a revision of the economic bamboos of the world.

Doctor Hitchcock arrived in Manila June 9 and spent 19 days in the islands, mostly in Luzon. He visited Los Baños and from there ascended to the summit of Makiling, 3,300 feet, through virgin forest. He also ascended Baguio, 5,000 feet, and Santo Thomas, 8,000 feet.

At the close of the year he was en route to Japan by way of Hongkong. In Japan he intends to visit Hokone and to ascend Mount Fuji and other mountains, studying and collecting bamboos. From there he will proceed to China, and, if time permits, to Java, returning to Washington the latter part of December.

RESEARCHES ON A MULTIPLE-CHARGE ROCKET FOR REACHING GREAT ALTITUDES.

As mentioned in my last report, Prof. Robert H. Goddard, of Clark University, is working under a grant from the Hodgkins fund of the Institution, on a multiple-charge rocket for exploring the unknown upper layers of the earth's atmosphere. During the year the work has consisted entirely of the construction and test of a small model, illustrating the multiple-charge principle.

The experiments and tests carried on during the year have been specifically for the purpose of eliminating jamming, of improving and simplifying the firing devices, of securing proper protection for the propelling charges, and of overcoming difficulties introduced by changes in the manufacture of materials used.

A parachute device for preventing damage to the rocket and any apparatus or instruments carried has been made which operates for a fall of 60 feet. In addition to this, a modification has been constructed suitable for operating the parachute after a short fall in rarefied air, such as is to be encountered at high elevations.

The intention has been to demonstrate as early as possible a model multiple-charge rocket such as has been mentioned, a successful demonstration of which, it is believed, should show clearly that a larger multiple-charge rocket, constructed upon the same lines, will make possible the reaching of great altitudes.

MEETING IN HONOR OF MADAME CURIE.

A meeting in honor of Madame Curie, the codiscoverer of radium, was held in the auditorium of the National Museum the evening of May 20, 1921, by the Madame Curie Committee of Washington. The address of welcome to Madame Curie was delivered by your secretary, honorary chairman of the committee, who said in part:

In your personality as a child of Poland and a citizen of France you recall to us the inspiration that has come to our national life from those lands and as a scientist the inspiration and courage that you have given to every research student in America. * * * Your discovery of the two elements, polonium and radium, and the determination of their atomic weights and many of their properties, awards you a place in the foremost rank of the world's research workers, while your generous devotion to science and the application of your work to the alleviation of human suffering, asking for yourself only the privilege of continuing your work, place you among the great benefactors of mankind. Moreover, your work has another great underlying value. It has demonstrated to the public at large and to those who control Government expenditure for scientific research, the inevitable ultimate benefit to humanity of research in the domain of pure science, however distant it may seem in the beginning from useful application.

The meeting was also addressed by Miss Julia Lathrop, and a lecture on radium was given by Dr. R. A. Millikan, of the University of Chicago.

CINCHONA BOTANICAL STATION.

The lease of the Cinchona Botanical Station held by the Smithsonian Institution on behalf of several American botanical agencies, mentioned in previous reports, was terminated on June 30, 1921, as the colonial Government of Jamaica decided to retain the station for the use of British and Jamaican botanists. It is hoped that the Institute for Research in Tropical America, recently organized in this country, will soon be able to provide some station affording advantages similar to those of the Cinchona station for botanical research in the Tropics.

PUBLICATIONS.

There were issued during the year by the Smithsonian Institution and its branches 113 volumes and pamphlets. Of these publications there were distributed a total of 142,208 copies, including 255 volumes and separates of the Smithsonian Contributions to Knowledge, 12,922 volumes and separates of the Smithsonian Miscellaneous Collections, 24,423 volumes and separates of the Smithsonian annual reports, 89,000 volumes and separates of the publications of the National Museum, 12,795 publications of the Bureau of American Ethnology, 2,000 special publications, 14 volumes of the Annals of the Astrophysical Observatory, 40 reports on the Harriman Alaska expedi-

tion, 414 reports of the American Historical Association, and 345 publications presented to but not issued by the Smithsonian Institution.

The publications of the Institution and its branches are the principal means of carrying out one of its chief purposes, the "diffusion of knowledge." They cover practically every branch of science and are distributed to libraries, educational and scientific establishments, and interested individuals throughout the world. The annual report of the Institution contains a general appendix made up of articles reviewing in a semipopular style recent advances and interesting developments in all branches of science. These reports are printed in large editions, and the increasing demand for them indicates that there is a growing interest in scientific matters among the American people. The publications of the National Museum and the Bureau of American Ethnology are described in detail in the appendices devoted to those branches of the Institution.

Seven papers of the Smithsonian Miscellaneous Collections were issued during the year, among which may be mentioned as of special interest a seventh revised edition of the Smithsonian Physical Tables, a comprehensive work for which there is great demand among industrial concerns, engineers, and educational institutions; the annual Smithsonian Exploration Pamphlet, which describes briefly the results of the Institution's explorations and field-work during the year and is profusely illustrated with interesting photographs taken by the explorers in various parts of the world; and a reprint of the Smithsonian Mathematical Tables, one of the Institution's series of tables which includes the Physical Tables mentioned above, the Meteorological Tables, and the Geographical Tables.

Allotments for printing.—The congressional allotments for the printing of the Smithsonian reports and the various publications of the branches of the Institution were practically used up at the close of the year. The allotments for the coming year ending June 30, 1922, are as follows:

For the Smithsonian Institution: For printing and binding the annual reports of the Board of Regents, with general appendices, the editions of which shall not exceed 10,000 copies, to be immediately available.....	\$20,000
For the annual reports of the National Museum, with general appendices, and for printing labels and blanks, and for the bulletins and proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding in half morocco or material not more expensive, scientific books and pamphlets presented to or acquired by the National Museum Library.....	37,500
For the annual reports and bulletins of the Bureau of American Ethnology, and for miscellaneous printing and binding for the bureau.....	21,000
For the annual report of the National Gallery of Art and for printing catalogues, labels, and blanks.....	1,000

For miscellaneous printing and binding :

International Exchanges	200
International Catalogue of Scientific Literature.....	100
National Zoological Park.....	200
Astrophysical Observatory	4,000

For the annual report of the American Historical Association..... 7,000

Committee on printing and publication.—The function of the Smithsonian advisory committee on printing and publication is to examine and make recommendations concerning all manuscripts offered for publication by the Institution or its branches. During the year eight meetings were held and 94 manuscripts were acted upon. The membership of the committee is as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Dr. George P. Merrill, head curator of geology, National Museum; Dr. J. Walter Fewkes, chief, Bureau of American Ethnology; Mr. N. Hollister, superintendent, National Zoological Park; and Mr. W. P. True, editor of the Smithsonian Institution, secretary.

LIBRARY.

Accessions to the library of the Institution during the year numbered 11,948 volumes and pamphlets, of which 6,250 went to the Smithsonian deposit in the Library of Congress; 938 to the Smithsonian office, Astrophysical Observatory, Freer Gallery of Art, and National Zoological Park libraries; and 4,760 to the National Museum library. Many of the packages of books and pamphlets received by the library through the International Exchange Service consisted of publications issued by several foreign countries during the years 1914 to 1920 which had been held awaiting normal transportation facilities. This unusual number of receipts necessitated more than twice the amount of cataloguing accomplished by the library staff during the previous year.

Among the many valuable accessions to the scientific library of the National Museum may be mentioned the entire geological library of the late Dr. Joseph P. Iddings, which forms the most important acquisition to the geological section of the library since the foundation of the department in 1880.

Two new branch libraries were created during the year, namely, the National Gallery of Art library and the Freer Gallery of Art library. The former is administered by the National Museum library, but the latter is a distinct unit consisting of publications needed for reference use in connection with the Freer art collections.

NATIONAL MUSEUM.

The past year was an unusually busy one for the National Museum. The National Gallery of Art was separated from the Museum and created a separate administrative unit under the Smithsonian Insti-

tution: the Aircraft Building was opened to the public; and considerable additional work was entailed by the schemes for reclassification and reorganization of the Government departments, the putting into effect of the retirement system for civil employees, and the impending inauguration of the budget system for Government accounts.

Other changes in the organization of the Museum besides the separation of the National Gallery of Art include the removal of the division of graphic arts from the department of anthropology to the department of arts and industries; the creation of the division of history, formerly under anthropology, as an independent division; the subdivision of the division of marine invertebrates; and the grouping of all strictly engineering units, including mineral and mechanical technology, under one curator. The Museum, as now organized, comprises an administrative office, 4 scientific and technical departments, and 1 independent division, with a total of 49 recognized subdivisions.

The total number of specimens acquired by the Museum during the year was 338,120. This new material is described somewhat in detail in the report of the administrative assistant in charge, appended hereto, so that it is necessary to mention here only a few of the most interesting accessions. In anthropology, a collection of rare Mission Indian baskets was received from Miss Ella F. Hubby, and Dr. W. L. Abbott contributed some very interesting stone fetishes and ancient pottery from Santo Domingo. An immense collection of skeletal material was received from the College of Physicians and Surgeons, New York City, which will double the value of the collections in the division of physical anthropology.

The most notable accession to the department of biology was the material collected in Australia by Mr. Charles M. Hoy through the generosity of Dr. W. L. Abbott. A great collection of Japanese mollusks was donated by Mr. Y. Hirase, of Japan, forming one of the most valuable accessions ever received by the division of mollusks. The geological accessions included a quantity of South American material comprising Bolivian tin and tungsten ores, rare copper minerals from Chile, and a representative series of ores from Argentina. An interesting exhibit of precious opal in the matrix, ranging in color from the "black" opal to the pale opalescent tints, was presented by the Rainbow Mining Co., of Nevada. An extensive series of igneous rocks from islands of the Pacific and Indian Oceans, collected by the late Dr. Joseph P. Iddings, was presented by his sister, Mrs. Francis D. Cleveland.

The division of textiles received specimens of the fabrics used in the construction of airplanes for military use, and many beautiful specimens of silks, fur fabrics, plushes, and velvets contributed by

American manufacturers to show the progress of textile industries in this country. The division of medicine acquired, among other valuable material, a series of the most frequently prescribed pharmaceutical preparations, arranged, according to their therapeutic action, into 26 groups. The collection of aeronautical material in the division of mechanical technology was enriched by the acquisition of the original hydroplane model devised by Mr. Edson F. Gallaudet. This model was constructed and experimented with in 1898, and is particularly interesting in that means for lateral control and wing warping were incorporated, but in practice were unsuccessful.

The Herbert Ward collection of African ethnologica was shipped from Paris on June 25, 1921, but was not received at the Museum until after the close of the fiscal year. This rare and valuable material includes 19 pieces of sculpture by Mr. Ward and about 2,600 specimens of the arms and implements of the Africans of the Congo.

The usual large number of meetings and congresses were held in the auditorium of the Museum. Visitors to the Natural History Building during the year totaled 364,281 for week days and 103,018 for Sundays, and to the Arts and Industries Building 286,397. The publications issued during the year comprised the annual report, 8 bulletins, and 60 separate papers including 4 parts of bulletins, 5 parts of the Contributions from the National Herbarium, and 51 proceedings papers.

NATIONAL GALLERY OF ART.

An event of great importance in the development of Washington as an art center was the organization, at the beginning of the year, of the National Gallery of Art, previously a dependency of the United States National Museum, as a separate administrative unit under the Smithsonian Institution. This step, which was made possible through an appropriation contained in the sundry civil bill for the year 1921, will enable the institution to carry out the provisions of the act of establishment in which art was placed on an equal footing with science in the proposed development of the institution. The art feature has heretofore been held in abeyance through lack of funds and of proper means for administering the National Gallery. All that is now necessary for the full development of the Nation's art collections is a suitable building to house the treasures at present on hand and contributions that may confidently be expected in the future.

The first real impetus to the growth of the gallery was the bequest of a valuable collection of art works by Harriet Lane Johnston in 1906. Since that time the national collections have increased rapidly, chiefly through gifts and bequests of art works by patriotic

citizens, until now the value of the material already assembled is estimated at several million dollars. The gallery has never had any funds for the purchase of pictures until recently, when a liberal private fund has become available. The will of the late Henry Ward Ranger provides that the interest on the sum of \$200,000 shall be used for the purchase of works of art which may ultimately come to the National Gallery. A number of valuable paintings have already been purchased from this fund.

Two other agencies which will do much toward building up the National Gallery are the National Portrait Committee, which secured for the gallery the portraits of many of the distinguished leaders of America and the Allies in the World War, and the National Gallery of Art Commission, whose functions are "to promote the administration, development, and utilization of the National Gallery of Art, including the acquisition of material of high quality representing the fine arts and the study of the best methods of exhibiting material to the public and its utilization for instruction."

An illustrated catalogue of the present collection was in preparation and nearly ready for the press at the close of the year. A start was made, also, during the year toward the building up of an art library. The income from a bequest to the Smithsonian Institution by the Rev. Bruce Hughes, of Lebanon, Pa., will be used for the purchase of reference works on art which will serve as a permanent memorial to the donor.

FREER GALLERY OF ART.

In the first report on the Freer Gallery of Art (Appendix 3 of this report), the curator, Mr. J. E. Lodge, gives a list indicating the nature and number of objects in the Freer collection, all of which had been received at the Freer Building by November, 1920. Art works of various kinds from the following sources are included in the collection: American, Babylonian, Byzantine, Cambodian, Chinese, Cypriote, Egyptian, Greek, Italian, Japanese, Korean, Near Eastern and East Indian, Palmyran, and Tibetan. The total number of art objects, including a small amount of unclassified material, is 9,566.

During the past year, the collection was unpacked and the objects placed in their respective storage spaces. The Japanese pottery and Chinese paintings were classified, and the task of checking and cataloguing the entire collection was begun. The interior fittings of the building were completed during the year, with the exception of a few minor items, and in June the Institution formally accepted the building from the architect, Mr. Charles A. Platt.

The plan of installation is first to catalogue and arrange the collections in the storage rooms so that they will be accessible for study, then to select objects for exhibition, and finally to arrange the public exhibits. This method delays the opening of the building to the public, but in the long run of years it will make the collection more valuable for purposes of study and exhibition, and will assure a far more accurate record of every object. Such an art gallery as this will exert its influence for centuries, and a year of delay in the beginning will not materially decrease its usefulness.

BUREAU OF AMERICAN ETHNOLOGY.

The Chief of the Bureau of American Ethnology calls attention to the desirability of increasing the membership of the staff in order to meet the requirements of modern ethnological research. The service that the bureau should render to the state is somewhat different from what it was when the bureau was organized by Major Powell, its director. American ethnology of the future, having passed its descriptive stage, will demand a synthetic comparative treatment of the vast mass of facts accumulated in the last 25 years. There is an urgent call for generalizations that will be immediately useful to the community; and as there is an ever-growing interest in the history of the Indians, the future of this science lies along the line of the historical development and appreciation of pre-historic culture.

Nature has made the Rocky Mountains a vacation ground for the people of this country who love mountain scenery, and parks and monuments containing natural attractions are being set aside by presidential proclamation and placed under the direction of the Department of the Interior. One line of usefulness that ethnology can follow is to turn the minds of our people to the educational value of this area.

The aim of the chief during the year has been to cover as fully as possible with the funds available the comprehensive fields of the ethnology and archeology of the American Indian. This plan embraces the many aspects of the cultural life of the Indians, their languages, dwellings, social and religious customs, music, mythology, and ritual. In many cases it is urgent that this valuable material be recorded immediately, as certain of the tribes are rapidly approaching extinction. It is the purpose of the chief to increase as much as possible the field-work of the bureau, especially in the branch of archeology, which is becoming more and more popular as shown by the increasing demand for publications on this subject. Researches were carried on during the year on the Algonquian In-

dians, the Iroquois, various members of the Muskogean stock, Kiowa, Pueblo, Osage, Pawnee, and others. Archeological explorations were conducted in Texas, Missouri, Tennessee, Kentucky, Colorado, New Mexico, and the Hawaiian Islands.

Successful archeological field-work was accomplished by Dr. J. Walter Fewkes on the Mesa Verde National Park, Colo. An extremely interesting ruin on which work was begun during the previous year was completely excavated and repaired. Owing to its undoubted use in connection with the worship of fire by the Indians, it was named Fire Temple. In Tennessee a number of prehistoric mounds were excavated which yielded interesting and valuable data on the Indians of that region, and similar work was conducted in Texas under the auspices of the bureau. Researches on Indian music were continued by Miss Densmore, the music of the Papago being studied this year.

INTERNATIONAL EXCHANGES.

The work of the exchange service was greatly increased during the past year owing to the resumption of exchange relations with Germany. The total number of packages of publications handled during the year was 451,471, an increase of 82,099 over the total for the preceding year. The weight of this material was 605,312 pounds, an increase of 108,934 pounds.

During the year exchanges of publications were inaugurated with the Czechoslovak Republic and with the Polish Government. Exchange relations will be established with Roumania and Jugoslavia as soon as transportation and other facilities are sufficiently stabilized.

To the list of countries receiving full sets of United States Government documents there was added the Government of Poland, making a total of 57 foreign depositories, while to the list receiving partial sets were added Latvia and the Library of the League of Nations at Geneva, bringing the total number of partial sets up to 39.

As an example of the value of the exchange service in securing special series of publications in this country for establishments abroad, a set of publications which would tend to make the United States better known in Belgium was obtained from the various Government bureaus in this country and forwarded to the Société Belge d'Études et d'Expansion, at Liege, at their request.

NATIONAL ZOOLOGICAL PARK.

That the National Zoological Park is becoming more and more valuable to the people of Washington and out-of-town visitors from all parts of the country as a source of recreation and natural history

instruction is evident from the fact that the record of attendance has again been broken during the past year. The previous year's visitors numbered 2,220,605, which figure was this year exceeded by 171,232, making a total of 2,400,837. One hundred and twenty-four schools and classes, numbering 13,629 individuals, visited the park during the year for instruction purposes. The number of animals exhibited to the public is greater than at any time since 1912, while the number of species represented in the collection is greater than ever before. The scientific importance and monetary value of the collection also are much greater than in any previous year. Gifts of animals during the year numbered 178, including many rare and valuable specimens. Mr. Isaac Ellison, of Singapore, presented the park with a male orang-utan, the first of these interesting animals to be shown for many years. Mr. Victor J. Evans, of Washington, continued his previous generosity to the park by presenting a young Kadiak bear, a pair of birds of paradise, a species never before shown here, and some valuable parrots. A full list of the animals presented and their donors is given in the full report on the Park, Appendix 6. Many valuable specimens were also secured by exchange and transfer, and a few by purchase. The total number of animals in the collection on June 30, 1921, was 1,545, representing 478 species, an increase over the year before of 118 individuals and 59 species.

Owing to a drop toward the end of the year in the cost of food for the animals, it was possible to undertake a few much-needed and long-deferred improvements. Sections of roads were rebuilt and repaired, one of the fords across Rock Creek was rebuilt with cement, a sidewalk was laid from the much-used Harvard Street entrance, the great flight cage for birds was scraped and painted, and several minor improvements were completed. With the aid of a small sawmill, 140,000 feet of lumber and 80,000 shingles were salvaged from dead chestnut trees in the park.

The purchase of land necessary for the protection of the Connecticut Avenue entrance, mentioned in several previous reports, was completed during the year, and a small unexpended balance of the money available for this purpose was reappropriated for the purchase of certain much-needed lots near the Adams Mill Road entrance.

The most urgent needs of the park are a suitable public restaurant building, a building for the exhibition of small mammals, and funds for the completion of grading and filling operations, which would provide a large area of flat space for deer and other animals, and would make possible the elimination of a dangerous curve in the main automobile road.

ASTROPHYSICAL OBSERVATORY.

The most important event during the year was the location of a new solar observing station on Mount Harqua Hala, Ariz., probably the most cloudless region in the United States. This station, which was erected through the generosity of Mr. John A. Roebling, of New Jersey, will be used for the purpose of securing solar-constant observations on all possible days for several years, which it is hoped will furnish, in conjunction with similar observations to be made at the Smithsonian station at Montezuma, Chile, a sound basis for the study of the relation between solar variation and our weather conditions on the earth.

At Washington the preparation of Volume IV of the *Annals of the Astrophysical Observatory*, mentioned in last year's report, was brought nearly to completion. A large amount of delicate instrument work was carried out at the observatory instrument shop, and Doctor Abbot was invited by Doctor Hale, of the Mount Wilson Solar Observatory, to prepare a special spectrobolometer to observe the energy spectra of the stars. This extremely delicate apparatus was nearly completed at the close of the year.

In the field the usual solar observations were conducted at Mount Wilson, Calif.; Montezuma, Chile; and at the new station in Arizona. At Mount Wilson Dr. Abbot and Mr. Aldrich also carried on observations on the distribution of radiation over the sun's disk, and various investigations with the pyrhelimeter, the spectrobolometer, the pyranometer, and the Ångström pyrgeometer. The solar cooker, on which Dr. Abbot has been working for several seasons, was brought to perfection, and practically all the cooking operations required by the observers were performed with the apparatus.

At the new Arizona station observing was begun about the middle of September, and from then until February conditions were even better than had been hoped for. It was possible to make observations on about 70 per cent of the days during that period. March, April, and May were less satisfactory, but this was apparently due to the unusual character of the weather all over the world, and it is confidently hoped that continued observations of the sun here and at the Chile station will lead to important results bearing on weather prediction on the earth.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

This international cooperative enterprise has been in existence since 1900, having as its object the systematic indexing and classifying of all original scientific publications. Beginning with the litera-

ture of 1901, the catalogue has been completed through 1914, and there is now on hand much material from that date up to the present time.

Until the beginning of the late war the catalogue was practically self-supporting, but owing to the international chaos caused by the war the finances of the enterprise are now in a very precarious condition. For this reason the Royal Society of London, the financial sponsor of the catalogue, called a conference which was held in London during September, 1920. At this conference delegates were sent from 13 of the principal countries of the world, exclusive of the enemy countries, who were not included in the Royal Society's invitation. The United States was represented by delegates from the National Academy of Sciences, the National Research Council, the Smithsonian Institution, and by a representative from the Rockefeller Foundation, who had just returned from the Continent, where he had been making an investigation of the Concilium Bibliographicum of Zurich.

The consensus of opinion resulting from this meeting appeared to be that it was essential for all organizations, such as the International Catalogue and existing and proposed abstract journals, whose common aim is to supply information required by scientific workers and libraries, to cooperate for their mutual benefit, and that when some definite plan of consolidation was agreed on financial aid would be forthcoming. Plans looking to this most desirable condition are now under way, but it appears that for the present, at least, the necessary funds will have to be supplied from the United States, for although we have felt the burden of war expenses in this country our finances are not in the deplorable condition now common to all of the European countries, which, in addition to the havoc caused by the war, are at a very great additional disadvantage owing to the unprecedented condition of monetary exchange. There is no question as to the need of abstract journals for the immediate use of scientific workers and also of a catalogue and index as a permanent record of scientific literature for the use of libraries, as well as for scientific workers, and as the present organization of the International Catalogue has still the official support of all of the principal countries of the world, and as this organization was founded after years of endeavor by representatives of practically all of the scientific societies of the world, it would now be a calamity to allow it to lapse merely on account of temporary financial difficulties. I can not therefore too strongly urge that this assistance be furnished by some of the several wealthy organizations in this country whose aims are to further the interests of science. A more detailed account of the findings of the

conference and of the present condition of the catalogue will be found in the regular annual report of the United States Regional Bureau of the International Catalogue of Scientific Literature, appended hereto.

NECROLOGY.

EDWARD DOUGLASS WHITE.

Edward Douglass White, Chief Justice of the United States and chancellor of the Smithsonian Institution, died May 19, 1921. It is not necessary to here review the life of this distinguished American whose name has been for so many years before the public. At a special meeting of the Board of Regents held May 27, 1921, the following resolutions in memory of Chancellor White were adopted:

Whereas: The Board of Regents of the Smithsonian Institution having received the announcement of the death on May 19, 1921, of the Hon. Edward Douglass White, Chief Justice of the United States, Regent of the Smithsonian Institution for ten years, eight years of which he presided as chancellor:

Resolved, That the board here expresses profound sorrow at the passing away of their beloved colleague, who, as a statesman, jurist, and chancellor, brought always to his work that remarkable ability and high conception of duty that made him so strong an influence for good.

Resolved, That this minute be made a part of the records of the board, and that a copy of these resolutions be transmitted to the family of the late chancellor as an expression of the sympathy of the Regents at the irreparable loss sustained in the death of this distinguished public servant and citizen.

NELSON R. WOOD.

Nelson R. Wood, for over 32 years a taxidermist in the National Museum, died on November 8, 1920. Mr. Wood was one of the best men in the country in his line of work, and his loss is keenly felt by the Museum.

WILLIAM PALMER

William Palmer, taxidermist in the National Museum, died on April 8, 1921, after 30 years' faithful work in that capacity. Mr. Rathbun, late assistant secretary of the Institution, said of him:

Mr. Palmer has been one of the best all-round taxidermists and preparators in the Museum service. He is not only efficient and a hard worker, but is especially valuable because of his diversified talents, which permit of his being utilized in practically all zoological subjects.

JOSEPH P. IDDINGS.

Dr. Joseph P. Iddings, associate in petrology, department of geology, United States National Museum, died September 15, 1920. Doctor Iddings was one of the leading petrologists of America.

indeed of the world. He was for many years connected with the United States Geological Survey, and for a time professor of petrology in the University of Chicago. He was the author of two privately printed volumes on Rock Minerals and Igneous Rocks and numerous papers in the Government reports. He was also a joint author of the Quantitative System of Rock Classification. The important collections made and studied by him are all in the custody of the National Museum.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary.*

APPENDIX 1.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

SIR: I have the honor to submit the following report on the operations of the United States National Museum for the fiscal year ending June 30, 1921:

The fiscal year was an unusually busy one. The separation of the National Gallery of Art from the Museum, the completion of the building for the Freer collections, the opening of the Aircraft Building, the preparation of data for the schemes of reclassification of Government employees and reorganization of Government departments, the inauguration of the retirement system for civil employees, and the impending inauguration of a budget system for Government accounts, all added to the usual Museum activities of the year.

The National Gallery of Art, which had for a number of years been administered as the fine arts department of the Museum, became an independent bureau under the Smithsonian Institution on July 1, 1920, through provision for its separate maintenance in the sundry civil appropriation act for the year 1921. To the new bureau were transferred such of the Museum's collections as had been in the custody of the curator of the National Gallery of Art, consisting of paintings, sculptures, and a few miscellaneous pieces. For the present the gallery continues to be housed in the Natural History Building of the Museum.

Dr. William H. Holmes severed his connection with the Museum as head curator of anthropology on July 1, 1920, to become director of the National Gallery of Art, and carries with him to his larger field the good will of the entire Museum staff. When in 1906 it became necessary to provide a somewhat definite organization for the department of fine arts of the Museum, the curatorship of the National Gallery of Art was tendered to Dr. Holmes and accepted by him in addition to his duties then as Chief of the Bureau of American Ethnology. Since that time Doctor Holmes has given freely of his time and strength for the National Gallery without financial return. It is gratifying that he is now enabled to devote all of his energies to his chosen field.

As a separate administrative unit of the Institution a rapid growth is predicted for the National Gallery, of which the Freer collection, housed in its own building, forms a distinct unit. It is hoped that

in a few years an additional building, suitable for the permanent home of the National Gallery, will be authorized by Congress.

Dr. Walter Hough, curator of ethnology, was made acting head curator of the department of anthropology upon Dr. Holmes's resignation.

On April 31, 1921, the final work in the construction of the building for the Freer collections was completed, and the structure was formally transferred to the Smithsonian Institution, being accepted on May 3, 1921, just four years and seven months after ground was broken for its erection. That results were not reached earlier, as was anticipated at the beginning, was largely due to unforeseen delays incident to the war, but the work was at all times conducted with that deliberation and attention to details necessary to stability and permanency of structure—and these, it is believed, have been obtained. Planned with special reference to accommodating a collection whose various units were known, and of affording unusual facilities for study and research, the building is an object of art in itself, and is bound to become a mecca for art lovers from all over the world. Under the officer in charge of public buildings and grounds, driveways and walks were constructed leading to the Freer Gallery, and the land immediately surrounding it was seeded and has now been brought up to the standard of the balance of the Smithsonian Reservation. During the summer and autumn of 1920 the remaining portions of the Freer collections were brought to Washington from Detroit and stored in the building. The work of unpacking and installing the specimens was begun in the late autumn under the able direction of Miss Katharine N. Rhoades, who had been associated with Mr. Freer in their care for several years. It is anticipated that some time must elapse before the exhibits are all in readiness and the halls can be opened to visitors, as there is a great amount of critical study necessary before the objects can be accurately labeled and classified.

In December, 1920, Mr. John E. Lodge, curator of the department of Chinese and Japanese art in the Boston Museum of Fine Arts, was appointed curator of the Freer Gallery and placed in charge. The Freer Gallery is being administered as an independent unit of the National Gallery of Art, but the heating, lighting, and guarding of the building continue to be carried on in connection with the National Museum system, since the Freer Gallery is dependent upon the Museum plant for heat, light, and power.

By the opening to the public of the Aircraft Building, on October 7, 1920, the Museum added about 14,000 square feet of floor space to its exhibition halls. This metal structure, erected by the War Department on the Smithsonian Reservation in 1917 for the use of the

United States Signal Service, was transferred to the custody of the Smithsonian after the close of the war. In it has been assembled a collection of aircraft and accessories in production during the war period.

Changes during the year in the organization of the Museum, aside from the separation of the National Gallery of Art, included the removal of two divisions from the department of anthropology at the beginning of the year—the division of graphic arts being transferred to the department of arts and industries and the division of history becoming an independent division reporting directly to the administrative assistant in charge of the Museum. In biology, the division of marine invertebrates was subdivided on February 1, 1921, the collections of mollusks being segregated by the reestablishment of the division of mollusks. In the department of arts and industries a combination of all the strictly engineering units was effected in May, 1921, by the appointment of the curator of mechanical technology, Mr. Carl W. Mitman, as curator also of mineral technology. He will be aided by an assistant curator in each division.

The Museum lost by death during the year Dr. J. P. Iddings, associate in petrology, Messrs. Nelson R. Wood and William Palmer, taxidermists, and Mr. T. W. Reese, watchman.

As at present organized, the Museum comprises, besides an administrative office, 4 scientific and technical departments, and 1 independent division, with a total of 49 recognized subdivisions. The scientific staff of the Museum comprises 94 persons, of whom less than half receive pay from the Museum. This by no means represents, however, all the scientific workers on the collections, for the Museum also has much regular assistance from employees of various governmental agencies in Washington in classifying, arranging, and placing on exhibition specimens in their respective fields of investigation.

As the museum organization of the Government, the National Museum has important assistance from the executive departments and other governmental agencies. Particularly was this true during the fiscal year 1921. Credit is due to the Navy Department for transporting and installing in the Museum building many attractive exhibits in the World War collections; to the War Department for similar service, including the detail to the Museum of one officer for several months; to the Departments of Agriculture, Commerce, and the Interior, and the Bureau of American Ethnology for many valuable contributions of specimens and much assistance in classifying and labeling objects in the Museum; to the Interior Department also for transferring exhibition cases no longer needed by it; and to the Post Office Department for large series of valuable and interesting postage stamps.

This cooperation is mutual, as the Museum renders aid to other governmental establishments whenever possible, as evidenced by the work of Dr. Aleš Hrdlička for the Department of Justice, by which over a million of dollars in land and money was saved for the Indians.

The maintenance and operations of the National Museum for the fiscal year 1921 were provided for by items appropriated in the sundry civil and in two deficiency bills, amounting in all to \$483,322.70.

The item for preservation of collections, from which are paid the administrative, scientific, preparatorial and clerical staff, the watch, labor and cleaning force, and the cost of all preservatives, has remained at \$300,000 from 1911 until the present time. An additional \$12,620 granted for this year meant the extension of the service to cover the Freer Gallery of Art, for which it provided watchmen, cleaners, and clerical help and the necessary miscellaneous supplies needed in connection therewith. It afforded no cessation of the strictest economy by means of which only is it possible to continue the operations of the Museum. Present conditions can perhaps best be realized when it is stated that 10 years ago the item of \$300,000 was considered insufficient to cover the needs of the Museum in these lines. Within this decade, with its tremendous decrease in the purchasing power of the dollar, some 3,000,000 specimens have been added to the collections, the scope of the Museum has been materially enlarged, and an additional building has been added to the Museum group, aside from the Freer Gallery.

During this period, however, increases have been granted in the items for heating and lighting and for printing and binding, owing to the increased cost of coal and the tremendous increase in the cost of labor, paper, and other materials used in printing. On the other hand, even with the greatly extended service, the item for building repairs is now \$5,000 less than it was 10 years ago, at a time when the Natural History Building was new and naturally required comparatively little in the way of repairs. The amount for furniture and fixtures is likewise \$5,000 less than it was for a number of years prior to the war, when prices of labor and material were from 50 to 75 per cent lower.

Of the \$64,202.70 appropriated this year for printing, \$37,500 was the regular item and \$26,702.70 a deficiency item to permit of the completion during the year of an unusual accumulation of work at the Government Printing Office. The Museum printing had for several years been held back for lack of sufficient available funds.

A comparison of the operating expenses of the United States National Museum with museums of similar size and scope in this coun-

try and abroad is extremely interesting, and brings out very strongly the inadequacy of the appropriations, especially with reference to the salaries paid to all classes of its employees. The scientific staff is paid from 40 to 50 per cent less than scientific men of the same grade in similar museums elsewhere.

The upkeep of the buildings during the year involved the usual repair work, including the painting of walls and ceilings in several halls, the painting of all the exterior window frames of the Natural History Building, those of the east end of the Smithsonian Building, and a beginning on those of the Arts and Industries Building; and the painting of the roofs of the latter. A locker room for the engineer force was constructed at the east entrance, ground floor, of the Natural History Building, and the east court of that building was seeded with grass.

When the Freer Building was being planned, arrangements were made to procure heat, light, and power from the central heating plant, which the Institution was assured would be in a position to furnish the same before needed. In the absence of such service, however, the Freer Gallery was connected with the Museum power plant, from which was furnished this year the necessary heat, light, and power. This additional load on the Museum plant required the use of the old boilers in the Arts and Industries Building during the coldest portion of the heating season. By the removal of the old flat grates for burning anthracite coal in these boilers and the installation of hand-operated stokers, bituminous coal could be used without the production of unlawful smoke. The antiquated blow-off valve combination on the boilers in the Natural History Building was also replaced. Though the winter was a comparatively mild one, heat was supplied the buildings from October 6, 1920, to May 20, 1921, with a consumption of 3,224 tons of coal. The ice plant, in operation for 4,017 hours, produced 324.7 tons of ice. As a matter of economy the power plant was shut down as usual during July and August, 1920, and was again closed on June 4, 1921, the electric current being purchased from a private concern during the summer months.

The Museum acquired 62 exhibition cases and 165 pieces of storage, laboratory, and office furniture.

COLLECTIONS.

The total number of specimens acquired by the Museum during the year was approximately 338,120. Additional material to the extent of 794 lots, mainly geological, was received for special examination and report. About 25,000 specimens were sent out in exchange, for which the Museum received much valuable material.

The distribution of specimens for educational work was broadened this year to include objects from the department of anthropology. Of the 6,000 specimens distributed as gifts in aid of education, over 5,000 were comprised in classified and labeled sets of specimens prepared for schools and colleges, nearly 2,000 being ores and minerals. The other subjects represented were rocks, rock weathering and soil formation, mollusks, marine invertebrates, fishes, birds and birds' eggs, insects, pottery, and prehistoric implements.

Anthropology.—The department of anthropology accessions were scientifically more valuable than in the former year, because of the number of professionally collected specimens. The great majority of the accessions are unconditional gifts. The geographical source of the accessions in order is the United States, Asia, Africa, Polynesia, and scattering. The department received and recorded 2,324 specimens, and the work was well in hand at the close of the year.

Of especial note in ethnology are a collection of rare Mission Indian baskets given by Miss Ella F. Hubby, of Pasadena, Calif.; a remarkable Cowichan Indian blanket with totemic paintings, a gift of Mrs. Charles C. Hyde, of Washington, D. C.; a finely carved ancient wooden idol from Hawaii, collected many years ago by Rear Admiral J. V. B. Bleeker, United States Navy; a collection of carved horn dishes and spoons from the Flathead Indians, gift of Dr. E. A. Spitzka, of Washington, D. C.; and a group of ancient ivory fetishes from the Lower Congo, Africa.

The division of American archeology received a noteworthy collection from an ancient ruin near Taos, N. Mex., excavated by Mr. J. A. Jeancon for the Bureau of American Ethnology: antiquities from cliff dwellings, collected by Mr. N. M. Judd for the same bureau; and antiquities from the ruins of Chaco Canyon, N. Mex., collected by Mr. Judd while conducting the expedition of the National Geographic Society to this region. Very interesting carved stone fetishes and ancient pottery from Santo Domingo were contributed by Dr. W. L. Abbott.

Old World archeology reports the receipt of Buddhist bronze figurines from China and kakemonos from Japan, gift of Mrs. Murray Warner, of Eugene, Oreg.; other Buddhist bronze figures, given by Mrs. John Van Rensselaer Hoff, of Washington, D. C., fill gaps in the collection.

Physical anthropology received an immense consignment of skeletal material of individuals of known sex, age, color, and nationality. This collection, which doubles the value of the material in the division and will require several years' work to put in order and to catalogue, was received from the College of Physicians and Surgeons, New York City, through Dr. George S. Huntington. An important collection of human brains was donated by Dr. E. A. Spitzka, of

Washington, D. C. A number of skulls and skeletons of American Indians was added to the collection through the University of South Dakota and the Bureau of American Ethnology. These specimens are of much importance to the division.

Mr. Hugo Worch, of Washington, D. C., added to the Worch collection a copy of the Bach harpsichord and a dulcitone and 11 other pianos illustrating the history of the pianoforte. Mrs. Gouverneur Morris, of Washington, D. C., presented a piano handsomely decorated by Cottier, of New York.

A selection of rare oriental rugs from the collection of a connoisseur of Washington was hung in place of the collection previously on exhibit in the hall of art textiles.

The section of ceramics received a set of Japanese porcelain given Prof. Joseph Henry by the first Japanese minister to the United States, a bequest from Miss Caroline Henry. Miss Freeman and Mrs. B. H. Buckingham, of Washington, D. C., presented some richly decorated Japanese plaques.

Biology.—From the numerical standpoint, as well as from the standpoint of the scientific interest of the collections, the year was a very prosperous one for the department of biology. The outstanding features of this year's accessions are the Australian collections made by Mr. Charles M. Hoy, which were the result of Dr. W. L. Abbott's continued interest in the Museum, and the great collection of Japanese mollusks donated by Mr. Y. Hirase, of Kioto, Japan, one of the most valuable accessions that has ever come to the division of mollusks. Doctor Abbott is also responsible for the addition of an important collection of birds and mammals made by Mr. C. Boden Kloss in Siam, Cochin China, and Anam. While engaged in geological work in the Rocky Mountains, Secretary Walcott procured for the Museum several desired Canadian mammals, including mule deer and mountain goats. Another valuable accession is that of Dr. J. P. Iddings's collection of butterflies and moths, presented by the heirs of Doctor Iddings, consisting of about 2,500 named species, mostly from the Tropics and mounted ready for exhibition. Through the continued generosity of Mr. B. H. Swales, bird skins, representing 38 species and 7 genera not hitherto contained in the national collection, were added. The botanical material accessioned during the year embraced over 14,000 specimens from Haiti and Santo Domingo, collected by Doctor Abbott and Mr. Leonard, besides a large number of valuable collections both from the Old and the New World.

Geology.—The additions to the collections in this department showed a marked increase over those recorded in any one of the past 15 years. The total number of accessions listed is 231, a gain of 51

over last year and of 29 over the number recorded in 1914-15, next highest on the list.

The greatest bulk of material was received by transfer from the United States Geological Survey, but numerous valuable specimens were acquired chiefly by exchanges and gifts. These include a quantity of South American material comprising Bolivian tin and tungsten ores, and rare copper minerals from Chile, secured by Custodian F. L. Hess through Guggenheim Bros., New York City; Messrs. L. L. Ellis and Don Stewart, Oruro, Bolivia; and Prof. Joseph T. Singewald, of Johns Hopkins University. In addition, a representative series of ores from Argentina was presented by the ambassador, Mr. Tomas A. Le Breton.

Interesting additions were made to the exhibit of radioactive minerals, including carnotite, euxenite, torbernite, and uraninite.

The meteorite collection was augmented by representatives of four falls—Forsyth County, N. C.; Chinautla, Guatemala; Troup, Tex.; and Owens Valley, Calif.

New and rare specimens were added to the mineral collection chiefly through exchanges. An attractive suite of precious opal in the matrix, ranging in color from the "black" opal to the pale, opalescent tints, was presented by the Rainbow Ridge Mining Co., operating in Humboldt County, Nev., and important additions to the collection of cut gems were acquired through the Frances Lea Chamberlain fund.

The petrological collection was enriched by the extensive series of igneous rocks from islands of the Pacific and Indian Oceans, collected by the late Dr. Joseph P. Iddings and presented by his sister, Mrs. Francis D. Cleveland. Including also the scientific portion of Doctor Iddings's library as well as valuable collections assigned to other departments of the Museum, this is considered one of the most notable accessions of the year.

Accessions of paleontological material aggregate at least 50,000 specimens and include much material from foreign sources. Several thousand specimens of Cambrian fossils, collected chiefly by Secretary Walcott, and approximately 25,000 specimens of Silurian and Devonian forms from Maine are also among the year's acquisitions.

Vertebrate remains of unusual interest and in large quantity were obtained by Mr. J. W. Gidley, collecting in Arizona under the joint auspices of the National Museum and United States Geological Survey. A portion of this, including a rare species of mastodon and a large glyptodon, is sufficiently complete to afford material for restoration and exhibition.

New exhibits include two cases containing gem minerals in the matrix, supplemental to the gem collection; an entirely new installment of the exhibit illustrating radioactivity, and instructive and

showy biological series selected from the crinoid collection of Dr. Frank Springer; skeletons of the unique horned dinosaur, *Brachyceratops montanensis*, a wolverine, or *Gulo*, and a bear; and a biologic series illustrating the evolution of fossil plants.

Textiles, medicine, wood technology, and foods.—The collections under the supervision of the curator of textiles, which, besides textiles, embrace medicine, food, wood technology, and miscellaneous animal and vegetable products, were increased by many gifts and by transfer from other Government bureaus, amounting to nearly 1,000 objects. The most important of these are as follows:

From the Director of Air Service, War Department, specimens of the fabrics used in the construction and equipment of airplanes for military use; also examples of the same fabrics which had been converted to demonstrate the value for civilian use of the large surplus sold by the War Department to the public. There were added by gift many beautiful specimens of silks, fur fabrics, plushes, and velvets contributed by American manufacturers to show the progress of textile industries in this country.

The collections in the division of medicine were enlarged by a series of the most frequently prescribed pharmaceutical preparations, arranged, according to their therapeutic action, into 26 groups, by a large series of models, specimens, and photographs illustrating vaccine and serum therapy and arranged to demonstrate the methods used to combat smallpox, lockjaw, pneumonia, cerebrospinal meningitis, and hay fever. The collection illustrating pharmacy received valuable specimens of pharmaceutical apparatus and a large number of additional documents and publications bearing on the history of the United States Pharmacopœia.

Increased interest in the exhibition collections of the section of wood technology resulted from the gift by the British Government of a large section of one of the heavy oak beams taken from the roof of Westminster Hall during recent repairs to that historic structure. The roof was built under the orders of Richard II, in 1399, and oak timbers used therein, allowing for the age of the tree, must be at least 1,000 years old. The timber presented to the Museum exemplifies the durability of British oak and gives an idea of the beauty of the old craftsman's work.

Interest in the exhibits of the section of foods was increased by the addition of over 100 examples of canned fruits, vegetables, fish, and meats, which had been packed and preserved so as to present a most attractive appearance. This appetizing array of canned foods was all put up by children according to the cold-pack method and represented a selection from the jars winning prizes in 17 State contests between members of boys' and girls' canning clubs.

Mechanical and mineral technology.—One of the most important fields of the division of mechanical technology is educational exhibits visualizing the developments in the transportation systems of the country and the details of such progress. In this connection there were received a number of accessions, among which might be mentioned the gasoline automobile designed and constructed by Charles E. Duryea in 1892-93, which represents probably the beginnings of the automotive industry in this country. Another valuable accession was that of an operating model showing the cylinder mechanism of the type of internal-combustion engine developed by the Willys-Overland Co., of Toledo, Ohio.

In the branch of aeronautics the extensive collections of the Institution were further enhanced by the receipt of the original experimental hydroplane model devised by Mr. Edson F. Gallaudet, chairman of the board of directors of the Gallaudet Aircraft Corporation, East Greenwich, R. I. This model was constructed and experimented with in 1898, and is particularly interesting in that means for lateral control and wing warping were incorporated but in practice were unsuccessful.

The collections devoted to horology were increased through the efforts of Mr. George W. Spier, honorary custodian of watches, by the receipt of 10 valuable old watches; and Mr. Emile Berliner, of Washington City, very generously presented two gramophones of importance in the development of the talking machine, namely, the first commercial type developed in 1893, and an electrically operated machine devised by Mr. Berliner in 1896.

Among the accessions received in mineral technology was one consisting of over 400 specimens visualizing the interrelationship of the several chemical industries of importance in the production of aniline dyes, war gases, pharmaceuticals, and explosives.

Graphic arts.—The increment in graphic arts included an exhibit of hand-made paper: two books made along sixteenth century lines, all the work of one man, type, composition, and paper; facsimiles in type metal of 50 characters of supposedly the first font of metal type ever cast; wood block prints by Thomas Bewick, the father of wood engraving as used to-day; engraved wood block with progressive proofs in color by Rudolph Ruzicka; an exhibit of lead molding electrotypes and the McKee treatment of electrotype plates; photogelatine and photogravure work extending over 30 or 40 years; historical examples of rotary photogravure; beautiful examples of modern printing in black and white and color: soft ground etchings in color by Benjamin C. Brown; etched plate with trial proofs by Frank W. Benson, and dry-point etchings of President Harding, taken from life by Walter Tittle. To the photographic section were added a Jenkins camera making 30,000 exposures a minute: a print

from the first negative made in the United States by the Belin method of sending portraits by wire; Civil War photographs by Brady and large toned bromides of the World War showing comparative methods of warfare and photography; and illustrations of a number of hitherto unrepresented photographic processes.

History.—The historical collections received important additions during the past year. Those relating to the World War were for the most part of a naval character. The Navy Department transferred to the Museum a large aggregation of materials illustrating the part played by that branch of the service during the war, including naval airplanes of the type and design used for patrol and convoy duty during the conflict, models of naval vessels used during the same period, various examples of marine instruments used on these ships, and a large number of guns and miscellaneous ordnance material. The Navy Department also increased its exhibition by a number of naval objects captured from the enemy in the war zone. These include the engines of a German submarine, a submarine torpedo, and a number of smaller German naval projectiles. The exhibit of the Navy Department already presents in a striking and graphic manner the leading features of the work of the Navy during the war, and plans have been made to develop it into one of the most notable collections of the kind in existence. The numismatic and pictorial sections of the war collection received valuable additions, the former including a number of war decorations and commemorative medals and the latter two large paintings by Arthur M. Hazard, entitled "Not by Might" and "The Spirit of the Armistice." The collection was increased by British and Canadian uniforms, and documents relating to the services of Lieut. Louis Bennett, of the Royal Air Force, killed in action in France, given the Museum by his mother, Mrs. Louis Bennett, of Weston, W. Va.; and a collection of French military objects, including a steel listening post, a steel cupola with guns, a catapult, a Brandt cannon, a number of hand and rifle grenades, and miscellaneous relics presented by the French Government.

Of the antiquarian material may be mentioned a watch seal of carnelian set in gold, bearing the Washington crest and owned by General Washington subsequent to the War of the Revolution. This exceptionally interesting and valuable object was presented to the Museum by Mr. William Sloane, of New York. The National Society of Colonial Dames of America added to their collection a number of interesting pieces. Of special interest also is a very handsome silver punch bowl with tray, ladle, and 10 mugs, presented to Col. George Armistead by citizens of Baltimore in recognition of his services in connection with the defense of Fort McHenry, Baltimore Harbor, in 1814. These have been presented to the Mu-

seum by Mr. Alexander Gordon, jr., of Baltimore, a great grandson of Colonel Armistead. The military, the naval, the numismatic, and the philatelic sections of the original historical collections also received large additions during the year.

The Herbert Ward collection.—The Herbert Ward collection of African ethnologica, together with sculptures of African subjects by Mr. Ward, forming a unique assemblage illustrative of the culture of the unmodified natives, was packed and shipped from Paris on June 25, 1921. This collection, in accordance with Mr. Ward's wishes, was given to the Museum by his widow, Mrs. Sarita Sanford Ward. Mr. Ward was born in London, England, in 1862. At the age of 15 he set out on travels which took him over many of the unexplored lands of the world, and at 21 he began his work in Africa. While in the Congo, in the employ of the Belgian Government, he rendered important aid to Stanley in his explorations. For more than five years Mr. Ward lived among the natives of Central Africa, and during this time he developed the idea of preserving an epitome of the primitive life with which he was then surrounded and which would be an index of the primitive life of all men. The African Negro that Mr. Ward studied impressed him as possessing fine qualities of simple dignity and loyalty. Mr. Ward was by instinct and training a lover of art and constantly recorded his impressions of the natives at first hand. The records which he made on the spot were used in his subsequent famous works of sculpture, which portray the soul of Africa. Mr. Ward in this collection has contributed a noble effort for the benefit of art, science, and humanity.

Partello bequest.—By the terms of the will of Dwight J. Partello, offered for probate during the year, the Museum is bequeathed his collection of musical instruments, bows, and cases, gathered during many years of collecting; 37 paintings; a gold and silver bowl or casket presented to Mr. Partello by the Czar of Russia; and a diploma and medal awarded him for his exhibit of violins at the Chicago Exposition in 1893. This well-known collection illustrating the Italian school of violins is of great intrinsic value and numbers 25 instruments of the violin family, made by the best masters in pure construction, including Amati, Stradavari, Bergonzi, Guarnerius, and others. At the end of the year the estate had not been settled.

EXPLORATIONS AND FIELD-WORK.

Owing to very limited appropriations, the Museum is unable to undertake field-work except in cooperation with individuals or other scientific institutions where the expenses are mostly borne by them. The expeditions sent out during the past year have been financed almost entirely from outside sources.

Archeological survey in the Pueblo region.—Mr. N. M. Judd, curator of American archeology, made an extensive reconnaissance in Arizona and New Mexico in the summer of 1920 in connection with the projected archeological work to be taken up by the National Geographic Society, resulting in valuable accessions to the Museum. At the date of this report he was in the field conducting explorations in the ancient ruins of Chaco Canyon, N. Mex., for that society. Good results are reported in the preliminary stages of this work, which is expected to cover five summers. Under the arrangement with the society most of the specimens obtained will come to the National Museum.

Australian expedition.—Mr. Charles M. Hoy, who has been collecting vertebrates in Australia since June, 1919, supported by a fund placed at the disposition of the Institution by Dr. W. L. Abbott, continued his field-work during the year. He collected at several stations in South Australia, where he also visited Kangaroo Island, at two stations in West Australia, and in the Northern Territory. Forty-four days were spent in working an area of 30 miles in extent. Later on two camps were established in New South Wales, one near the highest point on the northern tableland at an elevation of 5,000 feet and one 1,000 feet lower. Altogether, the year's work was very successful. The two shipments received during the year totaled 571 mammals and 534 birds, well prepared, many of which were hitherto unrepresented in our collections. A number of interesting reptiles, amphibians, and marine invertebrates were also included.

Dr. Abbott's explorations in Santo Domingo.—Late in 1920 Dr. W. L. Abbott undertook personally another expedition, this time visiting the north side of Santo Domingo (Villa Riva, Pimentel, Catui, Mao, in the Yaqui Valley, and several points on the Samana Peninsula) and returning in May, 1921. He brought back a small but select collection of birds, but his main efforts were devoted to the collecting of plants, approximately 4,000 of which have been received and will doubtless prove of great value.

The Smithsonian African expedition.—The expedition mentioned in last year's report as having been sent out in conjunction with the Universal Film Manufacturing Co. to South and Central Africa concluded its biological work on July 14, 1920, after which Mr. H. C. Raven, the Smithsonian collector and naturalist, returned to the United States. Though not numerically large, the collections brought home are of unusual interest on account of the manner in which they supplement those obtained by other expeditions in which the Smithsonian Institution has been interested.

Field-work in vertebrate paleontology.—Early in the year Assistant Curator J. W. Gidley was detailed to visit Williamsburg, Va.,

to investigate a reported find of some fossil bones in that vicinity. These proved to be the remains of an extinct species of whale of Miocene age, but were incomplete and too badly damaged to make possible the recovery of a sufficient number for an exhibition mount.

Two other important field expeditions were undertaken by Mr. Gidley, the first as the result of reports from Mr. Kirk Bryan, of the United States Geological Survey, who had discovered some promising localities for fossil vertebrate remains while making an extensive survey of the underground water resources of the San Pedro Valley of Arizona. Mr. Gidley spent two months or more in the Arizona field, visiting three localities in the San Pedro Valley and one in Sulphur Springs Valley. The last yielded only fragmentary remains of Pleistocene mammals, but much better results were obtained in the San Pedro Valley, where two localities, one about 2 miles south of Benson, the other at the Curtis ranch, about 14 miles south of Benson, yielded remains of about 30 species, mostly mammals, which seem to represent a new or little-known Pliocene fauna. Mr. Gidley shipped 21 boxes, with an aggregate weight of about 4,630 pounds. A portion of this material will be suitable for exhibition, the most important being remains sufficiently complete to form the basis of skeleton restoration of a rare species of mastodon and a large edentate. Other remains represent extinct species of camels, carnivorous animals, rodents, turtles, and birds.

The second expedition, entirely under Museum auspices, included a trip to Agate Springs, Nebr., where was secured a large slab, or block of limestone, containing remains of the little rhinoceros, *Diceratherium cooki*. This will be cleaned and exhibited with the bones in situ.

Mr. C. W. Gilmore was detailed in April to visit a fossiliferous area some 36 miles north of Santa Fe, N. Mex., for the purpose of making collections of paleontological material, and for determining the advisability of reserving certain lands for national monument purposes. A skull, lower jaws, and other bones of an extinct rhinoceros, various limb and foot bones of a camel, and a small collection of miscellaneous specimens were obtained as a result of this trip.

Other expeditions in which the Museum was interested are briefly described in the first part of this report which relates to the affairs of the Smithsonian proper.

MEETINGS AND CONGRESSES.

The accommodations afforded by the auditorium and committee rooms in the Natural History Building were utilized on many occasions. A course of evening lectures on the history and nature of international relations, extending from October to May, was given under the auspices of the school of foreign service of Georgetown

University, while two local scientific societies, the Anthropological Society of Washington and the Entomological Society of Washington, made the building their regular meeting place.

The National Academy of Sciences held its annual meeting from April 25 to 27, the first evening being given over to an address by His Serene Highness, the Prince of Monaco, followed by a reception by the Regents and secretary of the Institution in the halls assigned to the National Gallery of Art. Other societies holding here their annual gatherings, some lasting several days, included the Northern Nut Growers' Association; the American Ornithologists' Union; the American Farm Economic Association; the American Society of Mammalogists; the Audubon Society of the District of Columbia; and the American Institute of Architects. In connection with the last, the Second National Architectural Exhibition, installed in the near-by lobby and foyer, was inaugurated by a special evening opening of the building.

During its convention in Washington in May, the American Federation of Arts held an afternoon session in the Museum auditorium, and the delegates were tendered a reception by the Regents and secretary of the Institution in the National Gallery of Art on the evening of that date, with a special view of the collection of war portraits, brought together by the National Portrait Committee as a nucleus of a national portrait gallery. In connection with the visit of Madame Marie Curie to this country, a meeting was arranged in her honor in the auditorium with a lecture by Dr. R. A. Millikan on radium, the exhibition halls on the two lower floors being thrown open for inspection during the evening.

The program of the Washington convention of the American Bankers' Association also included an evening reception by the Board of Regents and Secretary of the Smithsonian in the Natural History Building. The Southern Commercial Congress, during its meeting in Washington, used the auditorium for presenting to the Department of Agriculture a portrait of the late David Lubin, the Italian ambassador assisting in the ceremonies.

Meeting facilities were afforded governmental agencies as follows: The Bureau of Public Health Service of the Treasury Department, for an institute on venereal disease control, lasting several days, and for showing motion pictures relating to its work on several occasions; the Department of Agriculture, for numerous meetings and conferences in relation to the work of the Federal Horticultural Board, the Forest Service, the Bureau of Plant Industry, the States Relations Service, and the Bureau of Markets; the Army Medical School of the War Department, for a lecture by Dr. Hideyo Noguchi, and for the closing exercises of the 1920-21 session of the

school; the Post Office Department, for a lecture by Mr. D. F. Garland; the Commission of Fine Arts; and the Federal Board of Vocational Education. Single lectures were given under the auspices of the National Research Council, the Geological Society of Washington, the Washington Academy of Sciences, Georgetown University, and the Osteopathic Association of the District of Columbia.

At the First Pan Pacific Scientific Congress, held in Hawaii from August 2 to 20, 1920, the Museum was represented by the following members of the staff of the Smithsonian Institution: Mr. John B. Henderson, Regent of the Institution; Dr. Paul Bartsch; Dr. Gerrit S. Miller, jr.; Dr. T. Wayland Vaughan; and Mr. Gerard Fowke.

MISCELLANEOUS.

The attendance of visitors to the Natural History Building during the year aggregated 364,281 for week days and 103,018 for Sundays, being a daily average of 1.167 for the former and 1.981 for the latter. At the Arts and Industries Building the total attendance was 286,397, a daily average of 917. The Aircraft Building had an attendance of 31,235 for the portion of the year it was open, an average of 147 persons daily. The total attendance in the Smithsonian Building on week days was 90,097, an average of 288, and on the one Sunday 138.

The publications of the year comprised the annual report for 1920, 8 bulletins, and 60 separate papers. The latter consisted of 4 parts of bulletins, 5 parts of Contributions from the National Herbarium, and 51 proceedings papers. The total number of copies of publications distributed was about 89,000.

The library obtained, by purchase, gift, and exchange, 2,041 completed volumes and 2,719 pamphlets. The more important donations were from Mrs. Francis D. Cleveland, Dr. Charles D. Walcott, and Dr. W. H. Dall, the former contributing the scientific library of the late Joseph Paxson Iddings, petrologist.

While it is the primary duty of a museum to preserve the objects confided to its care, as it is that of a library to preserve its books and manuscripts, yet the importance of public collections rests not upon the mere basis of custodianship nor upon the number of specimens assembled and their money value, but upon the use to which they are put. Judged by this standard, the National Museum may claim to have reached a high state of efficiency. From an educational point of view it is of great value to those persons who are so fortunate as to reside in Washington or who are able to visit the Nation's capital. In its well-designed cases, in which every detail of structure, appointment, and color is considered, a selection of rep-

representative objects is placed on view to the public, all being carefully labeled individually and in groups. The child as well as the adult has been provided for, and the kindergarten pupil and the high school scholar can be seen here supplementing their classroom games or studies. Under authority from Congress the small colleges and higher grades of schools and academies throughout the land, especially in places where museums do not exist, are also being aided in their educational work by sets of duplicate specimens, selected and labeled to meet the needs of both teachers and pupils.

Nor has the elementary or even the higher education been by any means the sole gainer from the work of the Museum. To advance knowledge, to gradually extend the boundaries of learning, has been one of the great tasks to which the Museum, in consonance with the spirit of the Institution, has set itself from the first. Its staff, though chiefly engaged in the duties incident to the care, classification, and labeling of collections in order that they may be accessible to the public and to students, has yet in these operations made important discoveries in every department of the Museum's activities, which have in turn been communicated to other scholars through its numerous publications. But the collections have not been held for the study of the staff nor for the scientific advancement of those belonging to the establishment. Most freely have they been put at the disposal of investigators connected with other institutions, without whose help the record of scientific progress based upon the material in the Museum would have been greatly curtailed. When it is possible to so arrange, the investigator comes to Washington; otherwise such collections as he needs are sent to him, whether he resides in this country or abroad. In this manner practically every prominent specialist throughout the world interested in the subjects here well represented has had some use of the collections, and thereby the National Museum has come to be recognized as a conspicuous factor in the advancement of knowledge wherever civilization has a foothold.

Respectfully submitted.

W. LE C. RAVENEL.

Administrative Assistant to the Secretary,

In charge United States National Museum.

DR. CHARLES D. WALCOTT,

Secretary of the Smithsonian Institution.

APPENDIX 2.

REPORT ON THE NATIONAL GALLERY OF ART.

SIR: I have the honor to submit herewith the following report on the affairs of the National Gallery of Art for the year ending June 30, 1921.

ORGANIZATION AND HISTORY OF THE GALLERY.

The National Gallery of Art, which is the legal depository of all objects of art belonging to the Nation, has heretofore been administered in connection with the United States National Museum. By the action of the Sixty-sixth Congress in providing "for the administration of the National Gallery of Art by the Smithsonian Institution, including compensation of necessary employees and necessary incidental expenses," its connection with the Museum was severed and it became the seventh administrative branch under the Institution on July 1, 1920.

A full account of the inception of the art activities of the Institution and of the early struggles of the incipient Gallery of Art, prepared by the late Assistant Secretary of the Institution, Dr. Richard Rathbun, is given in Bulletin 70 of the United States National Museum (edition of 1916), and a brief résumé may be given here as a suitable introduction to the first annual report of the gallery under the new régime, and at the same time emphasizing the imperfectly recognized fact that art was placed on an equal footing with science in the foundation of the Institution.

The Smithsonian Institution was founded in 1846 by a fund provided by James Smithson and was organized under the control of a board of regents. By act of the Congress of the United States approved August 10, 1846, establishing the Smithsonian Institution, it was provided:

That, so soon as the Board of Regents shall have selected the said site [for a building], they shall cause to be erected a suitable building, of plain and durable materials and structure, without unnecessary ornament, and of sufficient size, and with suitable rooms or halls, for the reception and arrangement, upon a liberal scale, of objects of natural history, including a geological and mineralogical cabinet; also a chemical laboratory, a library, a gallery of art, and the necessary lecture rooms, etc.

Immediately upon the organization of the Board of Regents, in September, 1846, a committee from its membership was appointed to digest a plan for carrying out the provisions of this act. The committee's report, submitted on January 25, 1847, contained the following recommendations on the subject of the fine arts:

The gallery of art, your committee think, should include both paintings and sculpture, as well as engravings and architectural designs; and it is desirable to have in connection with it one or more studios, in which young artists might copy without interruption, being admitted under such regulations as the board may prescribe. Your committee also think that as the collection of paintings and sculpture will probably accumulate slowly, the room destined for a gallery of art might properly and usefully meanwhile be occupied during the session of Congress as an exhibition room for the works of artists generally; and the extent and general usefulness of such an exhibition might probably be increased, if an arrangement could be effected with the Academy of Design, the Arts Union, the Artists' Fund Society, and other associations of similar character, so as to concentrate at the Metropolis, for a certain portion of each winter, the best results of talent in the fine arts.

The Smithsonian Building was completed in 1855, and served for a period of eight years to accommodate the collections of all classes. Serious discouragement of the art interests in the Institution resulted from the disastrous fire, which in 1865 burned out the second story of the building, destroying its contents, including portions of the art collections. The remaining works were removed, the paintings and statuary to the Corcoran Gallery and the engravings to the Library of Congress. Many years later they were in large part returned to the Institution, and but little of importance transpired until 1906, when a collection of paintings and other art works was bequeathed to the Corcoran Gallery of Art by Harriet Lane Johnston, mistress of the White House during President Buchanan's administration, subject to the condition that should a national gallery be established in Washington they should become the property of that gallery. This led to an inquiry regarding the status of the Institution as a national gallery, and the question was referred to the Supreme Court of the District of Columbia, which rendered the decision that the Institution is the duly constituted National Gallery of Art. The text of the decision is as follows:

It is, therefore, on this eleventh day of July, in the year 1906, by the Supreme Court of the District of Columbia, sitting in Equity, and by the authority thereof, adjudged, ordered, and decreed.

That there has been established by the United States of America in the City of Washington a National Art Gallery, within the scope and meaning of that part of the codicil bearing date April 21, 1902, made by the said Harriet Lane Johnston to her Last Will and Testament, in the proceedings in this case mentioned, wherein she gave and bequeathed the pictures, miniatures, and other articles to the Trustees of the Corcoran Gallery of Art, and in the event of the Government establishing in the City of Washington a National Art Gallery, then that the said pictures and other articles above mentioned should be delivered to the said National Art Gallery and become its property; and that the said National Art Gallery is the National Art Gallery established by the United

States of America at, and in connection with, the Smithsonian Institution, located in the District of Columbia, and described in the Act of Congress entitled an Act to establish the "Smithsonian Institution" for the increase and diffusion of knowledge among men, approved August 10, 1846 (9 Stat. L., 103; Title LXXIII, sec. 5579, R. S., U. S.), and the subsequent acts of Congress amendatory thereof; and it is further adjudged, ordered, and decreed that the United States of America is entitled to demand and receive from the surviving Executors of the said Harriet Lane Johnston, the Complainants named in the bill of complaint in this case, all of the above-mentioned pictures, articles of sculpture, engravings, miniatures, and other articles, the same to be and become a part of the said National Art Gallery so established by the United States of America at, and in connection with, the said Smithsonian Institution.

* * * * *

WENDELL P. STAFFORD, *Justice*.

The collection was therefore assigned to its care. Since that time the national collections have increased rapidly, chiefly, however, through gifts and bequests of art works by patriotic citizens.

It is a noteworthy fact that until the beginning of the year 1920-21 no appropriation had been made for the gallery or for the purchase of art works, and no provision for the employment of a salaried curator or other employees of the gallery, all works of art being associated with the department of anthropology of the National Museum. It happened thus that the organization of the gallery as a separate unit of the Institution did not require any radical change in the personnel of the gallery, the curator of the department of anthropology, who had previously cared for the art collections, becoming director, and the recorder of that department becoming the recorder of the gallery.

THE HENRY WARD RANGER FUND.

Fortunately, a liberal private fund has recently become available for the increase of the collections. The will of the late Henry Ward Ranger provides the sum of \$200,000, the interest of which is to be devoted to the purchase of works of art for the National Gallery, the carrying out of the bequest being intrusted to the National Academy of Design. The provision is as follows:

All pictures so purchased are to be given by the Council to art institutions in America, or to any library or other institutions in America maintaining a gallery open to the public, all such gifts to be upon the express condition that the National Gallery at Washington, administered by the Smithsonian Institute, shall have the option and right, without cost, to take, reclaim, and own any picture for their collection, provided they exercise such option and right at any time during the five-year period beginning ten years after the artist's death and ending fifteen years after his death; and, if such option and right is not exercised during such period, the picture shall remain and be the property of the institution to which it was first given.

The purchases so far made by the council of the academy are as follows:

Title.	Artist.	Date of purchase.	Assigned to—
1918-19.			
1. December Uplands.	Bruce Crane.....	Apr. 27, 1919	Syracuse Museum of Art.
1919-20.			
2. Evening Tide, California.	Wm. Ritschel.....	Jan. 11, 1920	National Gallery.
3. Grey Day.....	W. Granville-Smith.....	do.	Do.
4. The Rapids.....	W. Elmer Schofield....	May 2, 1920	Brooklyn Museum.
5. The Orange Bowl.	Anna Fisher.....	do.	Rhode Island School of Design, Providence, R. I.
1920-21.			
6. The Flower Girl...	Helen M. Turner.....	Apr. 4, 1921	Detroit Institute of Art, Detroit, Mich.
7. Shrino of the Rain Gods.	E. Irving Couse.....	do.	Toledo Museum of Art, Toledo, Ohio
8. The Moate Range..	Aldro T. Hibbard.....	do.	Portland Society of Art, Portland, Me
9. A Corner in Central Park.	Arthur J. E. Powell.....	do.	Milwaukee Art Institute, Milwaukee Wis.
10. Central Park and the Plaza.	Wm. A. Coffin.....	do.	Brooks Memorial Art Gallery, Memphis, Tenn.

The advisory committee of the gallery took up the question of the acceptability of these works, but it was later decided that the question of acceptance could more appropriately await final consideration until the dates of recall provided for by the bequest, namely, the five-year period beginning ten years after the artist's death in each case.

THE NATIONAL PORTRAIT COMMITTEE.

A second agency of primary importance to the gallery and to American history is found in the organization and activities of the National Portrait Committee. In January, 1919, a number of patriotic citizens and patrons of art realized that if the United States was to have a pictorial record of the World War it would be necessary to take immediate steps. A number of the distinguished leaders of America and of the Allied Nations were approached and their consent secured for the painting of their portraits by prominent American artists. With the indorsement of the Smithsonian Institution as custodian of the National Gallery of Art, the American Federation of Arts, and the American Mission to Negotiate Peace, then in session at Paris, the National Portrait Committee came into being for the purpose of carrying out this idea and thus initiating and establishing in Washington a National Portrait Gallery. The members of the committee as organized are: Hon. Henry White, chairman; Herbert L. Pratt, secretary and treasurer; Mrs. W. H. Crocker, Robert W. deForest, Abram Garfield, Mrs. E. H. Harriman, Arthur W. Meeker, J. Pierpont Morgan, Charles P. Taft, Charles D. Walcott, and Henry C. Frick (deceased).

That the gift of these paintings to the National Gallery might be thoroughly national in character, it was decided that a group of these portraits, financed by the art patrons of any city, would be in-

scribed as presented to the National Gallery by that city and that a representative of that city should become an honorary member of the National Portrait Committee. It was further decided that a tablet or other permanent record in the National Portrait Gallery should bear the names of the National Portrait Committee, including the chairmen of all local committees; and that there should be a record of the names of each subscriber to the purchase fund.

Twenty portraits completed under this arrangement were exhibited in the National Gallery during the month of May, 1921; and these, with such others as may be subsequently completed, will be shown in a number of cities throughout the United States before being permanently installed in Washington. The exhibition is being circulated under the auspices of the American Federation of Arts. The portraits available for exhibition at the close of the year are as follows:

By Cecilia Beaux:

Admiral, Sir David Beatty.

Premier Georges Clemenceau.

Cardinal Desiré Joseph Mercier.

By Joseph De Camp:

Premier, Sir Robert Laird Borden.

General, Sir Arthur William Currie.

By Charles Hopkinson:

Premier Joan J. C. Bratiano.

Premier Nikola Pashich.

Prince Kimmochi Salonji.

By John C. Johansen:

Field-Marshal, Sir Douglas Haig.

Marshal Joseph Joffre.

Gen. Amando Diaz.

Premier Vittorio Emanuele Orlando.

Signing of the Peace Treaty, June 28, 1919

By Edmund C. Tarbell:

Marshal Ferdinand Foch.

Gen. Georges Leman.

Woodrow Wilson.

By Douglas Volk:

His Majesty Albert I of Belgium.

Premier David Lloyd George.

Gen. John Joseph Pershing.

By Irving R. Wiles:

Admiral William Snowden Sims.

The portraits to be added, according to the plans of the committee, are:

By Jean McLane:

Her Majesty Elizabeth, Queen of the Belgians.

Premier William Morris Hughes.

Premier Eleutherios K. Venizelos.

By Edmund C. Tarbell:

Herbert Clark Hoover.

Through the courtesy of the American Federation of Arts these portraits were exhibited for a short period (May 5-22) in the large middle room of the gallery, where they attracted much attention. During this period the federation held its annual meeting in Washington, and on May 18 the Regents of the Smithsonian Institution gave a reception to the federation in the halls of the gallery, which was well attended by the members and by the citizens of Washington.

ART WORKS ACQUIRED DURING THE YEAR.

Aside from the Ranger purchases and the war portraits, the permanent acquisitions for the year are as follows:

An oil portrait of the late Julius Bien, painted by George Da Madura Peixotto in 1886. Gift of Mr. Julius Bien, of New York, through the Hon. Simon Wolf.

Monarch of the Farm (Norman bull), by William Henry Howe, N. A., painted in 1891. Gift of Mrs. William Henry Howe (Mrs. Julia May Clark Howe).

The Gathering Storm, by Eugène Louis Gabriel Isabey, 1864. Presented by Mrs. Gibson Fahnestock, in Memory of Maj. Clarence Fahnestock, of the American Expeditionary Forces.

Love and Life, by George Frederick Watts, R. A. Gift of the artist to the American people in 1893; accepted by act of Congress approved July 23, 1894; transferred to the gallery from the White House on March 21, 1921.

Portrait of a Gentleman (with white wig), attributed to Sir Godfrey Kneller (1646-1723). Bequeathed by Miss Caroline Henry.

Soldat de Crimée, by Harriet Blackstone. Gift of Mr. Barent G. Poucher and his wife, Florence Holbrook Poncher.

Portrait bust (white marble) of Hon. John Sherman, by Daniel Chester French, N. A., 1886. Gift of Lieut. John Sherman McCallum, through Mr. Charles Moore.

Portrait bust (bronze) of Brig. Gen. Joseph Wheeler, by William Rudolf O'Donovan, A. N. A. Gift of the memorial committee and contributors, through Mr. Henry Clews, surviving member of the committee.

The Wanderlusters' Rest, by William Henry Holmes. Gift of the artist.

The walk to Gethsemane, by Johannes Adam Simon Oertel. Gift of Mr. J. F. Oertel.

LOANS.

Although, on account of the shortage of space in the gallery, additional loans are not readily exhibited, the following were accepted during the year:

Portrait of Dr. William Healy Dall and a full-length portrait of George Washington, by Wilford Seymour Conrow. Lent by the artist. The latter was withdrawn before the close of the year.

Genevra dei Benci, attributed to Leonardo da Vinci (1452-1519). Lent by the Misses Janet R. and Mary Butties.

Athena, attributed to Simon De Vos (1603-1676). Lent by Miss May Warner. Withdrawn before the close of the year.

Five portraits; lent by Mrs. Archibald Hopkins (Mrs. Charlotte Everett Wise Hopkins), as follows: Col. Mark Hopkins, Continental Army, artist not given; Dr. Mark Hopkins, pastel by Sarony, of New York; Hon. Edward Everett, by Asher Brown Durand; Mrs. Edward Everett, by Gambadella; and Charlotte Brooks Everett (later Mrs. Henry Augustus Wise), by George P. A. Healy.

Portrait of Surgeon Baily Washington, jr., United States Navy (1787-1854), artist not given. Lent by Miss Alice M. Reading, his granddaughter.

Portrait of Miss Ellen Day Hale, by Mrs. Margaret W. Lesley Bush-Brown. Lent by the artist.

Christ in the Temple, by J. B. Tiepolo; The Doctor's Visit, by Jan Steen; Dedham Vale, by John Constable; and A Young Dutch Girl, by N. Drost. Lent by Mr. Ralph Cross Johnson.

Portrait of Mrs. Charles Eames, by Gambadella. Lent by Mrs. A. Gordan-Cumming.

Portrait of George Washington, by Rembrandt Peale; portrait of John Van Schaick Lansing Pruyn, by Charles Loring Elliott. Lent by the Hon. Charles S. Hamlin.

Seven Cameos—the Pickering Dodge collection. Lent by Mrs. Charles W. Rae.

Portrait bust (bronze) of Maj. Gen. George Owen Squier, Chief Signal Officer, United States Army, by Moses Wainer Dykaar. Lent by General Squier.

Portrait bust (marble) of the late Senator Justin Smith Morrill, of Vermont, by Preston Powers. Lent by Dr. Charles L. Swan through Senator W. P. Dillingham.

Statue of Pan (white marble). Lent by Brig. Gen. George P. Scriven, United States Army.

DISTRIBUTION.

Loans have been withdrawn by the owners as follows: Full-length portrait of George Washington, by Wilford S. Conrow, returned to Mr. Conrow on his request. Athena, attributed to Simon De Vos, was withdrawn by Miss May Warner.

In November, 1920, five paintings, the property of the National Gallery, by five living American artists, were lent to the American

Federation of Arts to be associated with twelve other notable paintings from other sources on an exhibition circuit, which included Davenport, Iowa; Moline, Mich.; Syracuse, N. Y.; Memphis, Tenn.; Oklahoma City, Okla.; Jackson, Mich.; and Ann Arbor, Mich. The five paintings—*Caresse Infantine*, by Mary Cassatt; *A Family of Birches*, by Willard Metcalfe; *The White Parasol*, by Robert Reid; *November*, by Dwight Tryon; and *Southwesterly Gale*, by Frederick J. Waugh—were returned to the gallery near the close of the fiscal year.

Mrs. Augusta H. Saint-Gaudens withdrew her bust of Lincoln for a Saint-Gaudens exhibit at the Carnegie Institute, Pittsburgh, Pa., in the early part of 1921. It was returned to the gallery at the close of the exhibit.

THE NATIONAL GALLERY OF ART COMMISSION.

An important forward step in the development of the gallery was made during the year. On May 27, 1921, the Board of Regents of the Institution, having the future of the gallery in mind, took the initial steps in the establishment of the National Gallery of Art Commission, formulating a plan of organization and naming the following board to take the steps necessary to its elaboration:

Public men interested in fine arts: W. K. Bixby, Joseph H. Gest, Charles Moore, James Parmelee, Herbert L. Pratt.

Experts: John E. Lodge, Frank Jewett Mather, jr., Charles A. Platt, Edward W. Redfield.

Artists: Herbert Adams, Edwin H. Blashfield, Daniel Chester French, Gari Melchers, William H. Holmes.

Dr. Charles D. Walcott, secretary of the Institution, was named a member of the commission *ex officio*.

The primary functions of the commission are "to promote the administration, development, and utilization of the National Gallery of Art, including the acquisition of material of high quality representing the fine arts; and the study of the best methods of exhibiting material to the public and its utilization for instruction."

At the first meeting of the commission, June 8, the organization was completed and committees were appointed to take charge of the various branches of the work. These are: Executive committee, Charles Moore (chairman), Herbert Adams, Daniel Chester French, W. H. Holmes (secretary), James Parmelee, and Charles D. Walcott; advisory committee (chairman to be named), Herbert Adams, Edwin H. Blashfield, W. H. Holmes, Gari Melchers, Charles A. Platt, and Edward W. Redfield; and 12 special committees: (a) On ancient European paintings, Frank Jewett Mather, jr., chairman; (b) on prints excepting the oriental, James Parmelee, chairman; (c) on

sculpture. Herbert Adams, chairman; (*d*) on American paintings, Edward W. Redfield, chairman; (*e*) on mural paintings, Edwin H. Blashfield, chairman; (*f*) on ceramics, Joseph E. Gest, chairman; (*g*) on oriental art, John E. Lodge, chairman; (*h*) on modern European art, Gari Melchers, chairman; (*i*) on architecture, Charles A. Platt, chairman; (*j*) on portrait gallery, Herbert L. Pratt, chairman; (*k*) on textiles, ————, chairman; and on building, Charles Moore, chairman. The executive committee met and organized on June 17, 1921, and at the close of the year considerable progress had been made in the organization of the special committees.

The value of the National Gallery collections already in hand is estimated at several million dollars, their acquirement being due entirely to the generous attitude of American citizens toward the National Gallery of Art, no single work of painting or sculpture now in its possession having been acquired by purchase. It can hardly be doubted that when a building is provided in which contributions can be cared for, and exhibited to the public in the manner they deserve, many collectors seeking a permanent home for their treasures will welcome the opportunity of placing them in the custody of a national institution. The providing of a suitable building for the gallery is all that is necessary to make Washington in the years to come an art center fully worthy of the Nation.

The act of Congress establishing the institution provided for a department or gallery of the fine arts and limited its scope to paintings, sculpture, engravings, and architectural designs—limitations which experience has shown lack elasticity, since the fine arts extend in various directions into other fields of culture. The chief difficulty in confining the collections to this narrow field is that, while the institution has depended, and must depend very largely, on gifts and bequests for its development, these gifts and bequests contain a large percentage of art material quite outside of the limitations indicated, as illustrated in the Freer, the Harriet Lane Johnson, and the Pell collections. It would thus appear that the gallery may well anticipate that when a building is provided for art, the scope of the subject matter will necessarily extend to all branches furnishing art material rising into the realm of the fine arts, as manifestly contemplated in the organization of the gallery commission.

A chief undertaking of the year was the preparation of an illustrated catalogue of the collections, which is practically ready for the printer at the close of the year. An illustrated catalogue of the Ralph Cross Johnson collection of paintings by old masters, written by Mr. George B. Rose of Little Rock, Ark., was published in the September (1920) number of the journal, *Art and Archaeology* (Vol. X, No. 3), and copies of this have been on sale during the year in the room devoted to these works.

LIST OF PUBLICATIONS.

FINE ARTS.

The National Art Committee Exhibition of War Portraits: Signing of the Peace Treaty, 1919, and Portraits of Distinguished Leaders of America and of the Allied Nations. Painted by Eminent American Artists for Presentation to the National Portrait Gallery. National Gallery of Art, under Direction of the Smithsonian Institution, Washington, D. C., May 5 to 22, 1921. Catalogue of the Portraits by Florence N. Levy. 30 pages and cover, illustrated. Irving Press, New York, 1921. Copyright, 1921, by The National Art Committee.

Rose, George B. The Ralph Cross Johnson Collection in the National Gallery at Washington, D. C. 24 illustrations. *Art and Archaeology*, Vol. X, No. 3, Sept., 1920, pp. 75-110.

A critical and appreciative review of the collection of twenty-four old masters of the Florentine, Bolognese, Venetian, Flemish, Dutch, and British schools presented to the National Gallery by Mr. Ralph Cross Johnson, of Washington, followed by an editorial announcement of the separate organization of the National Gallery of Art, pp. 109-10.

LIBRARY—THE HUGHES ALCOVE.

Considerable advance was made during the year in the accumulation of an art library, numerous art books and art periodicals having been added to the publications previously acquired by the gallery. By the will of the Rev. Bruce Hughes, of Lebanon, Pa., who died on March 20, 1916, a sum estimated at about \$9,000 was bequeathed to the Institution, "the sum so received to be invested and the income alone used to found the Hughes Alcove of the said Smithsonian Institute." It is intended to devote this income to the interests of the National Gallery, as the Institution feels that the desire of the testator can most fittingly be accomplished by the establishment and maintenance of an alcove or section in the library of the gallery, for reference works on art which shall serve as a permanent memorial to the founder. No part of the fund has as yet been expended.

GALLERY HOUSING.

The national collection of art works so far as intrusted to the Smithsonian Institution, were first accommodated in the Smithsonian Building and later in the National Museum Building, now the Museum of Arts and Industries. In 1910 they were transferred to the central sky-lighted hall of the recently erected Museum of Natural History. This hall was appropriately subdivided by partitions for the purpose. The space thus made available is, however, entirely inadequate to the actual needs of the gallery, and until an additional building is provided expansion must be at the further expense of the already seriously embarrassed natural history and associated departments.

The art collections are open to the public on every week day during the year, holidays included, from 9 o'clock a. m. to 4.30 o'clock p. m., and on Sundays from 1.30 to 4.30 p. m.

Respectfully submitted.

W. H. HOLMES,

Director, National Gallery of Art.

DR. CHARLES D. WALCOTT,

Secretary, Smithsonian Institution.

APPENDIX 3.

REPORT ON THE FREER GALLERY OF ART.

SIR: I have the honor to submit the first annual report on the Freer Gallery of Art, for the year ending June 30, 1921.

THE COLLECTION.

The entire Freer collection and all other objects delivered to the Smithsonian Institution, Freer Gallery of Art, by the executors of the will of Charles L. Freer, reached the building by November, 1920, and on June 15, 1921, receipt in full of all objects thus delivered was formally acknowledged by the Institution. The following list is offered as an indication of the nature and number of the objects received.

WORKS OF ART.		<i>Chinese.</i>	
<i>American.</i>		Furniture	22
By James McNeill Whistler.		Glass	14
Drawings	117	Ivory, bone, horn, and mother-of-pearl	8
Engravings (wood)	3	Jade and other hard stones	593
Etchings, including dry-points	683	Lacquer	17
Lithographs	194	Metal work:	
Paintings—		Bronze	678
Oils	67	Iron	19
Watercolors	47	Pewter	8
Pastels	40	Silver	20
Peacock room and 17 wainscot panels.		Paintings	1,255
Plates (copper)	38	Pottery	481
By other artists:		Sculpture.	
Paintings—		Stone	183
Oils	96	Wood	13
Watercolors	6	Textiles	183
Pastels	47		
Silver-points	3	<i>Cypriote.</i>	
Pottery	31	Glass	1
Sculpture, bronze	2	Metal work, gold	1
<i>Babylonian.</i>		<i>Egyptian.</i>	
Metal work, bronze	1	Glass	1,391
<i>Byzantine.</i>		Ivory, bone	4
Crystal	1	Metal work:	
Manuscripts, Greek Biblical, complete and fragmentary	29	Bronze	7
Metal work, gold	8	Gold	1
Paintings, illustrations	16	Pottery	254
<i>Cambodian.</i>		Sculpture:	
Ivory	6	Stone	34
Metal work, bronze	4	Wood	6
		<i>Greek.</i>	
		Metal work, bronze	2
		Pottery	1

<i>Italian.</i>		<i>Near Eastern and East Indian--Contd.</i>	
Furniture	1	Paintings	139
Pottery	4	Pottery	317
Textiles	1	Textiles	16
<i>Japanese.</i>		<i>Palmyren.</i>	
Lacquer	29	Sculpture, stone	1
Metal work:		<i>Tibetan.</i>	
Bronze	42	Paintings	13
Iron	4	<i>Unclassified.</i>	
Silver	1	Metal work	49
Paintings	804	Pottery	10
Pottery	821	Sculpture, stone	57
Print blocks (wood)	20	Textiles	11
Sculpture:		Miscellaneous materials	50
Stone	3	STUDY ACCESSORIES.	
Wood	60	Dies	2
Textiles	79	Electrotype plates	107
<i>Korean.</i>		Library:	
Glass	7	Books	2,344
Jade and other hard stones	4	Manuscripts	3
Metal work:		Reproductions	170
Bronze	189	Rubbings	222
Gold	6	Photographs:	
Silver	2	Lantern slides	3,179
Pottery	229	Negatives	693
Sculpture, stone	14	Print blocks (wood)	8
<i>Near Eastern and East Indian.</i>		Whistleriana.—19 portraits of Whistler, reproductions, photographs, clippings, Whistler letters, and other documents.	
Books, illustrated	18	EQUIPMENT.	
Ivory	1	Office, storage, and gallery furniture, etc	122
Metal work:			
Bronze	3		
Silver	19		

Work accomplished during the year includes unpacking and checking the collection and placing the objects in their respective storage spaces; examination and classification of the Japanese pottery and Chinese paintings; urgently needed restoration work on 27 oil paintings; renumbering, measuring and cataloguing of the entire collection. This latter task, though well under way, is by no means completed.

ACQUISITIONS BY PURCHASE.

Sculpture, stone:

Chinese, period of the Six Dynasties. Two large slabs carved in high relief with Buddhist scenes.

Chinese, T'ang? A tiger.

Photographic negatives—70, representing objects in the Freer collection.

BUILDING AND INSTALLATION.

The principal work accomplished during the year includes completion of certain electrical equipment and of gallery equipment such as register faces, pipe rails, and skylight glass; the installation of two additional lavatories and a carpenter's workshop; the provision of asbestos screens for the windows of the peacock room to prevent condensation of moisture on the glass; the building of partitions in

study room 2; the construction of storage cases for Chinese and Japanese panel pictures, for pottery, and for stone sculpture. Still under way is the rebuilding of the dais in gallery 18; the recoloring of the gallery walls throughout; the construction of storage bags and boxes for Japanese screens.

Early in June, the Institution formally and with certain reservations accepted the building from the architect, Mr. Charles A. Platt.

Thanks are due Mr. Stephen Warring, to whose care in packing and unpacking the collection may be attributed the transference of the whole from Detroit to the storages of the Freer Gallery without a mishap; Prof. Edward S. Morse for his expert opinion on the Japanese pottery; Mr. H. E. Thompson for his skillful work of restoration on the Whistler oil paintings; and, above all, Miss Rhoades and Miss Guest, both of the staff, without whose constant devotion to the Freer Gallery and its every interest, most of the progress here recorded would have been impossible.

Respectfully submitted.

J. E. LODGE,

Curator, Freer Gallery of Art.

DR. CHARLES D. WALCOTT,

Secretary, Smithsonian Institution.

APPENDIX 4.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

SIR: In response to your request, I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1921, conducted in accordance with the act of Congress approved June 5, 1920. The act referred to contains the following item:

American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archeologic remains, under the direction of the Smithsonian Institution, including necessary employees and the purchase of necessary books and periodicals, \$44,000.

In the expenditure of this money the chief has tried to cover the field as economically as possible and to broaden the researches of the bureau staff in order to include as many stocks of Indians as the limited appropriation will allow. The science of ethnology is so comprehensive and its problems so numerous and intricate that to do this scientifically is extremely difficult. Work has been done on the Algonquian, Iroquois, various members of the Muskogean stock, Kiowa, Pueblo, Osage, Pawnee, and others. The plan of work embraces many different aspects of the cultural life of the Indians, including their languages, social and religious customs, music, mythology, and ritual.

Researches have been made on the condition of the Indians in their aboriginal state before or directly after the advent of the Europeans and the desire has been to increase the relative amount of field-work. Archeological explorations have been prosecuted in Texas, Missouri, Tennessee, Kentucky, Colorado, New Mexico, and the Hawaiian Islands. This line of study is destined to become the most popular in anthropology, and publications on the subject are always eagerly sought by the correspondents of the bureau.

To the development in recent years of the movement known as "See America First" we owe in part the creation of a bureau of the Department of the Interior called the National Park Service. Incidentally the movement has stimulated a desire for research in both ethnology and archeology. Several monuments and one national park have been set aside by presidential proclamation to preserve

Indian relics which they contain. The main attractions of most of these reserves are ancient buildings more or less dilapidated and buried underground, and to increase their educational value it is necessary that they be excavated under the supervision of men trained in the scientific methods of the archeologist. They should also be repaired by equally competent hands. This work is now being shared with other institutions, but it is desirable that the Bureau of American Ethnology should continue to occupy a very prominent place in this work, in which it was the pioneer, as its appropriation was made in part for this service.

While the majority of these monuments are prehistoric cliff dwellings or pueblos situated in our Southwest, there are others of equal interest in other parts of the country. For instance, among the most instructive of these monuments is the Kasaan Monument, an abandoned Haida village situated in Alaska. This village has many of the old totem poles, several "grave houses," and other buildings still standing, but rapidly going into ruin, liable to be destroyed by fire or by vandals. It is very desirable that steps should be taken to preserve this deserted town and that ethnological studies be made before these relics are lost to science. The bureau is also contributing its part, in an unobtrusive manner, in the efforts to preserve Cahokia, the largest aboriginal mound in North America.

In his previous reports the chief has annually called attention to the time consumed by the staff in answering correspondence asking information regarding American ethnology and related subjects. Some of these letters request elementary knowledge, others demand more or less research. Whether for the one or the other purpose, they often necessitate investigation and absorb considerable time, which tends to distract the attention of the experts from intensive scientific research, thus causing the scientific output to be reduced to a greater or less degree. The chief regards this aspect of the work of the bureau as a very important one and indicative of the respect in which the bureau is held by its correspondents. For this reason replies have been prepared with great care, so that they may be reliable and authoritative.

FIELD RESEARCHES OF THE STAFF.

Two members of the staff, the chief and Dr. Truman Michelson, engaged in field exploration at some time during the year.

During the past year the chief made three visits to the Mesa Verde National Park, Colo.: one in July and August and another in November, 1920. On the second visit he was the guest of Mr. Stephen T. Mather, Director of the National Park Service. Mr. F. A. Wadleigh, general passenger agent of the Denver & Rio Grande Railroad,

and other gentlemen. The object of this visit was an inspection of past work in the park and formulation of plans for the future. The work in July and August was a continuation of cooperative work of the Bureau of American Ethnology and the National Park Service, with an allotment by the latter for the excavation and repair of the ruins in the park. A third visit was made in May and June, 1921, at the expense of the bureau.

In the report for 1920 attention was called to the beginning of the work of excavating a ruin known as Painted House, which is situated near the head of Fewkes Canyon, $2\frac{1}{2}$ miles south of Spruce Tree Camp. The result of this work, which was not finished at the close of last year, intensified the suspicion that this large cliff building was used for some communal purpose, and that it was connected with the worship of fire. The further excavation of this ruin was continued in July, when the floor of a great court was laid bare, verifying this suspicion and giving undoubted evidence of the existence of a large fireplace in the middle of the court. Taken in connection with other evidence, the statement that this was a building devoted to fire worship is practically proven. Fire Temple, as it may be designated, was completely excavated and its walls repaired. Ladders were so placed as to make it accessible to the public.

To facilitate the opening of Fire Temple to visitors, a road was constructed along the southern rim of Fewkes Canyon, ending in what is now called Sun Point, from which a magnificent view can be obtained of Sun Temple, Cliff Palace, and other important ruins of the Mesa. The importance of this road is reflected by its popularity; it is now the most frequented road on the park. Its construction also opened to visitors two little-known ruins near Fire Temple, one of which has been known for several years as Oak-tree House and the other as Fire Temple House. The walls of the latter were deeply buried, but were completely excavated, bringing to light a most interesting cliff dwelling, with kivas in a lower and storage rooms in an upper cave. A number of large ollas and a few unique specimens of black and white pottery and other artifacts were found in this ruin. The indications are that this was the dwelling and granary of the New Fire clan or of the priests who controlled the ceremonies in the Fire Temple. The ventilator of one kiva of this cliff dwelling resembled those of Sun Temple.

Oak-tree House lies in a symmetrical cave in full sight of Sun Point Road, about midway between Fire Temple and Sun Temple. The excavation of this ruin, which has unique features, was completed in September, and it is now in condition for inspection by visitors. A trail was constructed along the top of the talus connecting the ruins in Fewkes Canyon and ladders placed on the rim

of the canyon, making access to the ruins easy. These ladders follow the Indian trails, formed of foot holes cut in the perpendicular walls of the cliff.

One of the most interesting results of work in July, 1920, was the excavation of a tower situated in the cedars about a mile north of Spruce-tree Camp, and described in 1892 by Baron G. Nordenskiöld. This tower, which will in the future be called Cedar-tree Tower, enlarges our knowledge of the use of towers, as it is a type of a large number of these structures found on the Mesa Verde and in McElmo and Yellowjacket Canyons. The special feature of this type before excavation is indicated by a saucer-like depression on the surface of the ground south of the walls above ground. The significance of this depression was unknown previously to the work here mentioned. It marks the existence of a circular subterranean kiva which once had a vaulted roof and pilasters like those repeatedly described in cliff-house kivas. This tower was completely repaired and a road built around it to make it accessible to tourists.

In his field-work at Mesa Verde 30 years ago Baron Nordenskiöld, whose *Cliff Dwellers of the Mesa Verde* has become a classic, partially excavated a ruin in Soda Canyon about half a mile north of Cedar-tree Tower. The approach to this cliff dwelling was very difficult, but has been much improved by a trail constructed under the direction of the chief, making this ruin readily accessible, aided by several ladders where necessary.

The attractive feature of this ruin is a kiva the inner wall of which still retains on its plastering decorations almost as brilliant as when they were first made. On this account "Ruin 9," as it was formerly called, will be referred to in the future as Painted Kiva House. The decoration consists of a red dado below and white above, with triangles in clusters of three at intervals on the upper border of the dado. These decorations are identical with those on the court and rooms of Fire Temple and those used by the Hopi in decorating their walls 30 years ago. The row of dots which accompanies this mural decoration is also a common feature on the archaic black and white pottery from Step House, one of the most ancient cliff dwellings on the park.

Many specimens were found in Painted Kiva House, among which may be mentioned pottery, stone implements, metates, axes and celts, bone needles, fabrics, sandals and problematic wooden objects. Several ears of corn with kernels intact, seeds of squash and pumpkin, and abundant cornstalks and shucks left no doubt of the food of the inhabitants. A fragment of the so-called paper bread called by the Hopi *piki*, possibly over 500 years old, found at the bottom of an Oak-tree House kiva, allays any doubt on this point.

Future field-work on the Mesa Verde ought to be especially directed to the study of the relation of the Earth Lodge culture and that of the pueblo, in which is included the cliff dwellings and pueblos on top of the mesa. Both are characterized by distinctive pottery as well as architecture, although the essential features of the former are not very well known. Aztec and the Chaco ruins have local differences from the Mesa Verde, but it is not known which area first lost its population. Both populations flourished at about the same time, and it is believed the cliff dwellings on the Mesa Verde were older than the community houses of the Chaco Canyon.

In May, 1921, the chief resumed his work on the Mesa Verde, remaining there until the close of the fiscal year. During this time he completed the excavation of Far View House, and protected with a cement groat the tops of about two-thirds of all the walls of rooms.

About 385 feet north of Far View House, on higher land, in about the center of the cluster of 16 mounds that are included in the Mummy Lake group, the excavation of a most interesting building wholly buried under fallen walls was begun. Enough work was done to show that it is a remarkable type of building, consisting of a central circular tower with several subterranean rooms or kivas on the south side, overlooking a large cemetery. It has all the appearance of a necropolis of the cluster, and important results await its final excavation. Unfortunately work on this mound had to be suspended at the close of the fiscal year.

The Mummy Lake cluster of mounds is a typical village and is duplicated again and again on the mesa and the surrounding valleys. The complete village consists of buildings of several forms and functions, isolated or united, although the components are largely habitations of the unit type. Evidently the tower, with its accompanying kivas and cemetery, was the necropolis but not a habitation. The spade alone can divine the true meaning of members of this group.

In May the tops of all the walls of Sun Temple were recemented with groat to protect the walls from snow and rain, a work of no small magnitude.

During the entire year Mr. James Mooney, ethnologist, remained in the office, engaged in formulating replies to ethnologic inquiries and in digesting material from former western field seasons. No new material was collected or completed. His work during the winter was interrupted by a period of serious illness.

During the last fiscal year Dr. John R. Swanton, ethnologist, practically completed the proof reading of Bulletin 73, *Early History of the Creek Indians and Their Neighbors*, which is now going through the press. He also copied the Kossati texts which were collected a

few years ago, and completed the extraction of words from these texts, of which a beginning was made last year.

Doctor Swanton has added a few hundred cards to his material bearing on the economic basis of American Indian life, and has gone over Mr. James Murie's paper on the Ceremonies of the Pawnee twice, in order to make certain necessary changes in the phonetic symbols employed. He has also devoted some time to studies of the Alabama, Hitchiti, and Muskogee languages.

Doctor Swanton also continued the preparation of a paper on the Social Organization and Social Customs of the Indians of the Creek Confederacy, covering over 700 manuscript pages.

During the entire fiscal year Mr. J. N. B. Hewitt, ethnologist, was engaged in office work. His first work was devoted to the completion of the preparation by retyping of the Onondaga texts of the second part of the Iroquoian Cosmology, the first part having appeared in the Twenty-first Annual Report of the Bureau. Not only is the orthography of a large number of the native terms being standardized to conform in spelling with the other Iroquoian texts recorded by Mr. Hewitt but the statements and phrasing of numerous passages are also amplified or amended in such manner as to utilize information obtained by Mr. Hewitt since the recording of the original texts.

Mr. Hewitt also took advantage of the opportunity presented by the presence in Washington of Mr. George Gaboosa, a mixed-blood Chippewa Indian of Garden River, Ontario, Canada, who speaks both Chippewa and Ottawa dialects of Algonquian, by securing his aid in revising and translating a number of Ottawa texts supplied in 1900 by John Miscogeeon, an Ottawa mixed-blood, then in Washington, D. C. These texts are either myths or traditions embodying myths. Mr. Gaboosa supplied the Chippewa versions of these stories. In addition to this work he supplied interlinear translations to all the texts. The following is a list of these texts: The Myth of Nanabozho's Mother; Living Men Visit the Sky-Land; The Myth of Summer and Winter; The Myth of Daylight-Maker, or Daymaker; The Myth of Nanabozho.

Mr. Hewitt is at work on some material relating to the general culture of the Muskogean peoples, especially that relating to the Creeks and the Choctaw. In 1881-82 Maj. J. W. Powell began to collect and record this matter at first hand from Mr. L. C. Perryman and Gen. Pleasant Porter, both well versed in the native customs, beliefs, culture, and social organization of their peoples. Mr. Hewitt assisted in this compilation and recording. In this way he became familiar with this material, which was laid aside for lack of careful revision, and a portion of which has been lost; but as there is still much that is valuable and not available in print it was deemed wise

to prepare the matter for publication, especially in view of the fact that the objective activities treated in these records no longer form a part of the life of the Muskogean peoples, and so can not be obtained at first hand.

In addition to this material, it is designed to add as supplementary matter some Creek tales and mythic legends collected by Mr. Jeremiah Curtin.

The following brief list of topics treated may give some idea of the nature of these field notes: "Towns and clan lists," "Crime and murder," "The government of the clan," "The town government or organization of a town," "The council square," "The chief," "The system of councils," "The clan," "The ranks and the titles of persons," "The busk or puskita," "Medicine practices," "Names and naming," "Festivals," "Marriage customs," "Insanity," "Prophets," "Souls or spirits," "Mythic notes," and the short list of tales collected by Mr. Curtin. Much of the material here recorded is not available either in any other manuscript or in print.

Mr. Francis La Flesche, ethnologist, devoted nearly all of his time to putting into book form his notes for the second volume of his work on the Osage tribe. This task was twice interrupted by the reading of the galley and the page proofs of the first volume.

The second volume is nearing completion and embraces two versions of an ancient rite entitled "No'-zhi'-zho' Wa-tho', Songs of the Rite of Vigil." Up to this date the completed part of this manuscript, exclusive of the illustrations, contains 582 typewritten pages.

Sho'-ge-mo'-i', who gave the No'-zhi'-zho' ritual of his gens. the Tsi'-zhu Wa-shta-ge, died in the autumn of 1919. He was the fourth to die of the old men who aided in the recording of the ancient tribal rites of the Osage. Two old men died before the time set by them to give the ceremonials of their gentes arrived. Sho'-ge-mo'-i' remarked, as he was recording the child-naming ritual, to be published in a later volume, "The Osage people are fast dying out since they abandoned the supplicatory rites formulated by their ancestors."

The beginning of the fiscal year found Mr. J. P. Harrington, ethnologist, engaged in the preparation of his material on the language of the Kiowa Indians. The entire material was copied, collated, and analyzed, and constitutes a manuscript of more than 1,000 pages.

Kiowa is a typical Tano-Kiowan dialect, closely related in phonetics, vocabulary, and structure with the Tanoan languages of New Mexico. This proves again, as in the case of the Hopi, that culture areas cut across linguistic ones. The Tano-Kiowan is furthermore genetically related to the Keresan and Zuñian groups of New Mexico, also to the Shoshonean, and certain languages of California. Mr.

Harrington has in hand a comparative study of these languages which is very bulky.

Upon finishing the manuscript of the Kiowa paper, Mr. Harrington took up the Taos material, aided by a set of excellent texts dictated by Mr. R. Vargas, and comprising 400 typewritten pages. He finished this for publication before the close of the fiscal year.

On July 1, 1920, Dr. Truman Michelson, ethnologist, was at Tama, Iowa, engaged in researches among the Sauk and Fox of that State and preparing for publication by the Bureau a manuscript entitled "The Autobiography of a Fox Indian Woman," as far as practical in the field. A good deal of the work on this had been done in the previous fiscal year. Near the close of July he left for Saskatchewan, Canada, where he made a reconnaissance of the Plains Cree at File Hills Agency. From his study it appears that physically the Plains Cree have a cephalic index of about 79, thus belonging to the so-called Mississippi Valley type of North American Indian, which confirms the results of Doctor Boas's work many years ago. Linguistically Cree clearly belongs to the central division of Algonquian languages, but it is not as archaic as has usually been believed. The folklore and mythology here show from an analysis of the culture cycle that both woodland and plains elements are to be found, as well as a few plateau elements. Ethnologically we have the same combination, save that plateau elements are lacking.

Doctor Michelson returned to Washington at the close of August, where he completed the autobiography mentioned above, and in January submitted the manuscript for publication by the bureau. The remainder of his time at Washington was spent working out English translations of various Fox texts written in the current syllabary on mortuary customs and observances, as well as one or two folk tales.

Doctor Michelson left Washington in the latter part of May, 1921, to renew his researches among the Sauk and Fox of Iowa. Arriving at Tama near the end of the month, Doctor Michelson spent nearly all his time on the Fox mortuary customs and observations, mentioned above, with a view to their publication by the bureau. The Indian texts were restored phonetically, the translations corrected where needed, a grammatical analysis begun, and additional data secured, so that with the close of the fiscal year only about two weeks more field-work was necessary to complete the preparation of the volume so far as practical in the field. He took advantage of a favorable opportunity just before the end of the year to obtain data on the society called "Ki-wa-ka-mo A-ki."

While in the field and also in the office Doctor Michelson corrected proofs of Bulletin 72, *The Owl Sacred Pack of the Fox Indians*.

SPECIAL RESEARCHES.

Four manuscripts have been submitted during the year, entitled "Papago Songs," "Legend Music of the Papago," "Songs Connected With Expeditions to Obtain Salt," and "Viikita and Wakita Ceremonies of the Papago." This material comprises 148 pages of text, 75 transcriptions of songs (with phonographic records and technical analyses), and 27 photographic illustrations.

Special researches in the field were conducted by Miss Frances Densmore, Mr. W. E. Myer, Prof. J. E. Pearce, Mr. Gerard Fowke, and Mr. J. A. Jeancon.

In September Miss Densmore resumed her work on Papago music, and in December, 1920, returned to the Papago Reservation in Arizona, where she had worked a few months previously. She revisited San Xavier, but her work centered at Sells, formerly called Indian Oasis, but now the location of the Papago agency. Trips were made from there to Santa Rosa village, in the extreme north, and to Vomari village, in the extreme south of the reservation. Photographs, specimens, and records of songs were obtained at these places.

The principal subject of study at this time was the belief of the Papago in supernatural agencies controlling their food supply. Information was obtained regarding two ceremonies connected with this belief; i. e., the making and drinking of "cactus wine," and the Viikita. Numerous songs connected with these ceremonies were recorded.

Other classes of songs not previously recorded among the Papago were those received in dreams, those sung on expeditions to obtain salt, and those connected with stories told to children; also songs for success in the kicking-ball race and in hunting. Songs of war and of medicine were recorded, as well as others concerning the deeds of Elder Brother and including songs he was said to have sung after creating the spirits, winds, and clouds. Mention may be made of a song that was said to have been sung in order to produce the death of an aged woman. It was said that "her grandsons decided to kill her by means of a song," as her advanced age made her an incumbrance to them. Many songs have been recorded whose purpose was to procure health, but this is the first instance of a song intended to cause death. An important phase of the musical work was the hearing of a certain class of very old dance songs, a portion of which was in three parts, i. e., the voices of the men, the voices of the women singing the same melody an octave higher, and the voices of two or three women singing (for a brief period) a still higher part, different from the melody. This song was accompanied by the shaking of a gourd rattle and the striking of a basket drum, also by

stamping the feet, which is the most primitive manner of marking time. This dance is seldom held at the present time, but was witnessed on the desert late Christmas night.

As a development of the year's work Miss Densmore notes the importance of recognizing estheticism as a factor in Indian music. Her analyses have shown the presence of tones whose interval distances correspond to those of the first, second, third, and fourth upper partial tones of a fundamental. Thus, in a portion of his melody, the Indian appears to find satisfaction in intervals which are under natural laws. Apart from these tones and intervals it appears, from the evidence in hand, that his choice of tonal material is controlled by a sense of pleasure rather than by "keys" or "modes."

Miss Densmore continued work on her manuscript entitled "Chippewa Arts and Customs." Tabulations of the botanical portions of this book were made as follows: Lists of botanical names with bibliography, showing the uses of these plants by other tribes; lists of plants used as food, dyes, charms, and for general utility. Miss Densmore made more than 100 blue prints of birch-bark transparencies, showing a wide variety of interesting patterns. These transparencies are made by folding thin birch bark and indenting it with the teeth, the bark, when unfolded and held toward the light, revealing the pattern. This form of Chippewa art is almost extinct at the present time.

In September and October Mr. W. E. Myer, of Nashville, Tenn., excavated, under the auspices of the bureau, Indian village sites on the Gordon farm near Brentwood, Davidson County, Tenn., and also the Fewkes Group at Boiling Spring Academy, Williamson County, in the same State. The remains of an old Indian town at the Gordon site had walls and towers very similar to those of Pacaha, visited by De Soto in 1541. The walls covered an area of 11.2 acres.

When the former inhabitants for some unknown reason abandoned this site they appear to have left nearly all the buildings still standing. The locality was never again occupied or disturbed, but gradually the buildings of the silent and deserted town decayed, and whatever vestiges were not destroyed by the elements were slowly buried under a layer of black loam, which is now from 14 to 20 inches deep.

In the course of time the site of the buried village gradually became a beautiful grassy glade, set here and there with giant forest trees. The charm of the site appealed to one of the first white settlers, who built his home here and preserved the grassy glade for a lawn. No one suspected that an ancient Indian town was lying buried a few inches beneath the surface; but on the surface of this undisturbed lawn there were very faint saucer-shaped depressions and other evidences marking the sites of about 125 dwellings.

When the accumulated superficial black loam was removed from some of these circular depressions floors made of hard packed clay were brought to light. Some of these floors were very pleasing to the eye, being covered with a smoothed and polished coating of fine black, glossy material. The stone slab tops of the coffins of little children were exposed here and there, projecting an inch or two above the level of the floor.

A building was uncovered in the center of which was an altar filled with the pure white ashes of the ancient perpetual fire. The neighboring buildings were dwellings with fire beds used for domestic cooking. Stone metates, mullers, and other utensils used for household purposes were likewise found on the floors of these rooms.

Mr. Myer also explored an unnamed group of five mounds and a surrounding village site at Boiling Spring Academy in Williamson County, Tenn. At the request of many citizens of Tennessee he gave this the name of Fewkes Group in honor of Dr. J. Walter Fewkes, Chief of the Bureau of American Ethnology, who had visited the site, recognized its importance, and caused it to be explored.

Archeological field work was carried on by Prof. J. E. Pearce, of the University of Texas, in cooperation with the bureau. The area examined is situated in the vicinity of the city of Athens, in Henderson County, and during this work Professor Pearce received many courtesies from Judge A. B. Watkins, who has long manifested an interest in the archeology of the region. Professor Pearce finds that the eastern Texas region contains numerous mounds, village sites, and burial places, the objects from which are quite different from those found in the central and western portions of Texas. Three interesting mounds on the Morrall farm, 4 miles east of Cherokee County, were investigated. The highest of these mounds measures 80 feet across the base and 45 feet above the level of the base. The second mound is 180 feet long by 75 feet wide, but is only 15 feet high. Most of the mounds in the neighborhood of Athens have been plowed over and have no regularity in form. Several mounds situated in Harrison County, particularly those on the farm of Mr. Lane Mitchell, of Marshall, were examined and remains of earth lodges discovered, in the floor of which are central fire pits. These are probably recent. Numerous other sites were explored, yielding collections of pottery, stone implements, and other objects illustrating the life of the prehistoric aborigines of eastern Texas. Everything found implies that the Indians of this region lived in settled villages, were agriculturists, and made pottery of a high grade of excellence. Their culture was higher than that of the Indians who occupied the central region of Texas, investigated in 1919.

With a small allotment, Mr. J. A. Jeancon carried on important archeological work on a ruin at Llano, near Rancho de Taos, N. Mex., and obtained a valuable collection from a locality not represented in the Museum.

The architectural features and relations of the kiva and secular rooms of this ruin recall those of the cliff dwellings and pueblos of the Mesa Verde. The circular subterranean kiva that was excavated proved to be almost identical with a typical Mesa Verde kiva, verifying the legends that the modern Taos Indians are a mixed type containing Pueblo elements, probably of northern origin.

This kiva was embedded in house walls not free from secular buildings as in modern Taos and showed evidences of two occupations, or one kiva built inside another. It had no pilasters for the support of a vaulted roof, but there were in the floor four upright posts upon which a flat roof formerly rested. In the floor was an excellent fireplace and a plastered pit the purpose of which is problematical.

Mr. Jeancon's work attracted wide attention, and many persons visited the site while he was at work. Members of the chamber of commerce in Taos declared their intention to protect the excavated walls by means of a shed.

The chief visited the ruin before excavation began and inspected the excavations after they had been completed.

Mr. Gerard Fowke represented the bureau at the meeting of the Pan Pacific Congress in Honolulu and made a special study of the archeology of the Hawaiian Islands. He found that all the aboriginal remains on the islands are the work of the present Hawaiian race, indicating that when the earliest of these people came there the islands were without inhabitants. No archeological evidences were found of any prehistoric population: and, so far as can be ascertained, excavations would not result in the discovery of any specimens essentially different from those that can be seen on the surface or may be found slightly covered by very recent natural accumulation. At the same time, as all the remains are well worthy of study and preservation, the islands furnish opportunity for further research. His report on the temples, terraces, and other remains has been received and awaits publication.

Dr. Clark Wissler has given what time he could spare from his duties as chairman of the division of anthropology and psychology of the National Research Council to the completion of a Pawnee manuscript, in which he has been aided by Mr. James R. Murie. The music necessary for this has been transcribed by Miss Helen Roberts, and Dr. John R. Swanton has also assisted in this work.

During the fiscal year Mr. D. I. Bushnell, jr., completed a manuscript bearing the title: "Villages of the Algonquian, Siouan, and Caddoan Tribes West of the Mississippi." While engaged in the preparation of this manuscript he also secured many notes on the burial customs of the same tribes, and these, together with much additional material, are being used in the preparation of another manuscript, entitled "Burials of the Algonquian, Siouan, and Caddoan Tribes West of the Mississippi."

Miss Mary Lois Kissell has begun the preparation of the manuscript of a bulletin on weaving of the Northwest Coast Indians, which it is hoped will be later followed by others on other geographical areas.

A small allotment was given to Mr. Gerard Fowke to carry on special archeological work in Greenup, Ky., near Portsmouth, Ohio, on mounds figured and described by Squier and Davis, and T. H. Lewis. On the opposite bank of the Ohio River a celebrated cache of pipes has been found, and it was hoped that a similar deposit might be discovered near the effigy mound on the south side. The results of this examination were negative so far as the object desired was concerned, but resulted in several interesting observations of a nature too technical to discuss in this place.

EDITORIAL WORK AND PUBLICATIONS.

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, assisted by Mrs. Frances S. Nichols. The status of the publications is presented in the following summary:

PUBLICATIONS ISSUED.

- Bulletin 67. *Alsea Texts and Myths* (Fraeftenberg). 304 pp.
- Bulletin 71. *Native Cemeteries and Forms of Burial East of the Mississippi* (Bushnell). 160 pp., 17 pls.
- Bulletin 72. *The Owl Sacred Pack of the Fox Indians* (Michelson). 83 pp., 4 pls.
- List of Publications of the Bureau of American Ethnology. 41 pp.

PUBLICATIONS IN PRESS OR IN PREPARATION.

- Thirty-fourth Annual Report. Accompanying paper: *A Prehistoric Island Culture Area of America* (Fewkes).
- Thirty-fifth Annual Report. Accompanying paper: *Ethnology of the Kwakiutl* (Boas).
- Thirty-sixth Annual Report. Accompanying paper: *The Osage Tribe: Rite of the Chiefs; Sayings of the Ancient Men* (La Flesche).
- Thirty-seventh Annual Report. Accompanying paper: *The Winnebago Tribe* (Radin).

- Thirty-eighth Annual Report. Accompanying paper: An Introductory Study of the Arts, Crafts, and Customs of the Guiana Indians (Roth).
- Bulletin 73. Early History of the Creek Indians and Their Neighbors (Swanton).
- Bulletin 74. Excavation of a Site at Santiago Ahuizotla, D. F. Mexico (Tozzer).
- Bulletin 75. Northern Ute Music (Densmore).
- Bulletin 76. Archeological Excavations in the Ozark Region of Central Missouri (Fowke).
- Bulletin 77. Villages of the Algonquian, Siouan, and Caddoan Tribes West of the Mississippi (Bushnell).
- Bulletin —. Handbook of the Indians of California (Kroeber).
- Bulletin —. Mandan and Hidatsa Music (Densmore).

DISTRIBUTION OF PUBLICATIONS.

The distribution of publications has been continued under the immediate charge of Miss Helen Munroe, assisted by Miss Emma B. Powers. Publications were distributed as follows:

	Copies.
Annual reports and separates.	1,998
Bulletins and separates.	10,288
Contributions to North American Ethnology.	34
Miscellaneous publications	475
Total	12,795

ILLUSTRATIONS.

Mr. De Lancey Gill, illustrator, with the assistance of Mr. Albert E. Sweeney, continued the preparation of the illustrations of the bureau. A summary of this work follows:

Photographic illustrations for distribution and office use.	645
Negatives of ethnological and archeological subjects	351
Negative films developed from field exposures.	70
Photostat prints made from books and manuscripts.	120
Illustrations prepared and submitted for publication.	391
Line and color drawings.	195
Illustrations, proofs edited.	158
Lithographic proofs examined at Government Printing Office.	25,000

LIBRARY.

The reference library continued in the immediate care of Miss Ella Leary, librarian, assisted by Mr. Charles B. Newman and Mr. Samuel H. Miller.

During the year 775 books were accessioned, of which 50 were acquired by purchase, 325 by binding of periodicals, and 400 by gift and exchange. The periodicals currently received number about 900, of which 30 were received by subscription, the remainder being

received through exchange. The bureau has also received 269 pamphlets, giving at the close of the year a working library of 24,155 volumes, 14,777 pamphlets, and several thousand unbound periodicals.

During the year an increasing number of visitors have applied to the library for books. Information has been furnished and bibliographic notes compiled for the use of correspondents. The officials of the Library of Congress and of the Government departments have also made use of the library through frequent loans during the year.

In addition to the use of its own library, which is becoming more and more valuable through exchange and by limited purchase, it was found necessary to draw on the Library of Congress for the loan of about 500 books.

As mentioned in the last annual report, one of the most urgent needs of the library at the present time is more shelf room for its books.

COLLECTIONS.

The following collections, acquired by members of the bureau or by those detailed in connection with its researches, have been transferred to the United States National Museum:

Stone arrow polisher, presented to the bureau by Dr. Walter E. Roth, of Georgetown, British Guiana. (65625.)

Collection of archeological material, collected in the spring of 1920 in northwestern Arizona and southwestern Utah by Mr. Neil M. Judd. (65764.)

Pseudo stone implement, found by Rev. E. N. Kremer near Camphill, Cumberland County, Pa. (65795.)

Three human skulls and bones, collected by Dr. J. Walter Fewkes at Fire Temple Group, Mesa Verde National Park, Colo. (66011.)

Skeletons collected during the summer of 1920 near Nashville, Tenn., by Mr. W. E. Myer. (65115.)

Archeologica and skeleton, collected by Mr. J. A. Jeancon from a ruin near Taos, N. Mex., in the summer of 1920. (66156.)

Archeologica and human bones, found at Indian Hill, Fla. by Mr. Charles T. Earle. (65551.)

Skull bones and lower jaw, found at village site near Gatesville, Tex., by Prof. J. E. Pearce. (65334.)

PROPERTY.

Furniture and office equipment were purchased to the amount of \$140.83.

MISCELLANEOUS.

Clerical.—The correspondence and other clerical work of the office has been conducted by Miss May S. Clark, clerk to the chief. Mrs. Frances S. Nichols assisted the editor. Mr. Anthony Wilding served as messenger and typist to the chief.

Personnel.—Mr. Samuel H. Miller has been appointed to assist Miss Leary in the library in place of Mr. Charles B. Newman, transferred to the Smithsonian.

Mr. J. A. Jeancon, who served as assistant to the chief in the work at Mesa Verde, was later appointed temporary ethnologist, but at the close of two months' work in Washington, resigned to accept a position in the State Historical Museum, Denver, Colo.

Respectfully submitted.

J. WALTER FEWKES,

Chief, Bureau of American Ethnology.

Dr. CHARLES D. WALCOTT,

Secretary, Smithsonian Institution.

APPENDIX 5.

REPORT ON THE INTERNATIONAL EXCHANGES.

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1921:

The estimate submitted for the support of the service during 1921, including the allotment for printing and binding, was \$50,200, and this amount was granted by Congress. The repayments from departmental and various other establishments aggregated \$1,779.47, making the total resources available for carrying on the system of exchanges during the year \$54,979.47.

The work of the exchange service during the past year has been very heavy, due, principally, to the reopening of relations with Germany. One hundred and eighty-eight boxes were received from Germany and 691 boxes were forwarded to that country. These consignments weighed a total of 186,037 pounds, or about 31 per cent of the weight of all the packages handled by the exchange service during the year.

The total number of packages passing through the service during the year was 451,471—an increase over the number for the preceding year of 82,099. The weight of these packages was 605,312 pounds—a gain of 108,934. For statistical purposes the packages handled by the exchange service are divided into several classes.

The number and weight of the packages of different classes are indicated in the following table:

	Packages.		Weight.	
	Sent.	Received.	Sent.	Received.
			<i>Pounds.</i>	<i>Pounds.</i>
United States parliamentary documents sent abroad.....	147,133		72,549	
Publications received in return for parliamentary document ..		1,419		6,268
United States departmental documents sent abroad.....	175,007		243,288	
Publications received in return for departmental documents....		5,591		9,747
Miscellaneous scientific and literary publications sent abroad....	90,014		181,575	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States....		32,307		91,585
Total.....	412,154	39,317	497,412	107,900
Grand total.	451,471		605,312	

As explained in previous reports, the disparity between the number of publications sent abroad and those received in return is not so great as would appear from the above figures. Packages sent abroad in many instances contain only a single publication, while those received in return often comprise several volumes—in some cases the term “package” being applied to large boxes containing a hundred or more publications. Furthermore, some foreign establishments send their publications directly to their destinations in this country by mail and not through exchange channels.

As I have already stated, shipments were resumed during the year to Germany. Relations have also been reestablished with Austria. The steps taken by the Institution toward the reopening of exchanges with Roumania and the establishment of relations with the newly formed Government of Jugoslavia, referred to in my last report, have not yet led to a successful result. The Roumanian authorities state that, in view of the difficulties of railroad transportation, the service can not at the present time be reorganized, but as soon as those difficulties are overcome the Roumanian Government will at once resume the service. The Government of Jugoslavia, in a note received near the close of the year, states that it will be glad to renew the interchange of publications as soon as the Belgrade Exchange Bureau is reorganized. Conditions in Russia and Turkey have not yet reached a state where steps can be taken to renew the exchange of publications between those countries and the United States.

Reference was made in my 1920 report to the fact that an exchange of publications had been inaugurated with the Czechoslovak Republic. As a matter of record it should be stated here that notification was received through the Department of State from the Belgian ambassador in Washington of the adherence of the Government of Czechoslovakia to the exchange conventions concluded at Brussels on March 15, 1886. One of those conventions provides for the international exchange of official documents and scientific and literary publications; the other, for the immediate exchange of the official journal, parliamentary annals, and documents. Articles II and IX of the conventions provide that the States which have not taken part in the convention are admitted to adhere to it on their request, this adherence to be notified diplomatically to the Belgian Government and by that Government to all the other signatory States.

I am glad to report that the Polish Government has also adhered to the Brussels convention providing for the establishment of a system of international exchanges and that the *Bibliothèque du Ministère des Relations Extérieures*, at Warsaw, has been designated to assume charge of the Polish International Exchange Service. Under

date of May 14, 1921, the first shipment, consisting of 18 boxes, was dispatched to Poland.

The Government of the free city of Danzig, in reply to a letter from this Institution asking whether it would be willing to undertake the distribution of packages intended for correspondents in the territory comprising that city, stated that the Stadtbibliothek had been designated to act as its exchange bureau.

Among the requests received from foreign establishments for assistance in procuring especially desired publications may be mentioned one from the Société Belge d'Études et d'Expansion at Liège. That society stated that, having in view a closer relationship between its peoples and the nationals of friendly and allied countries, it had established a new service of general documentation, and was anxious to receive for the use of that service publications which would tend to make the United States better known in the Kingdom of Belgium. The Institution procured for the Society of Studies and Expansion from the various bureaus of this Government such publications as it was thought would answer the purpose in question.

Last year mention was made of the fact that a shipment weighing over 25,000 pounds had been made to the library of the University of Louvain, and that that consignment was the largest single shipment ever forwarded through the Smithsonian Exchange Service to one address at one time. While that statement still holds good, it might be of interest to note here that during the last three months of the current fiscal year three shipments were made to the German Exchange Agency for distribution to various addresses throughout Germany which weighed over 30,000 pounds each. These shipments, as I have mentioned in the foregoing part of this report, were made up of exchanges suspended during the war.

During the year 2,752 boxes were used in forwarding exchanges to foreign agencies for distribution, being an increase of 393 over the number for the preceding 12 months. This is the largest number of boxes shipped abroad through the exchange service in one year, being about 300 more than are handled during a normal year. It is, of course, due to the accumulations received for the countries with which exchange relations were resumed. The gross weight of the boxes forwarded abroad aggregated a total of 546,279 pounds, being an increase of 81,093 pounds over the preceding year.

Of the total number of boxes sent abroad, 383 contained full sets of United States official documents for authorized depositories and 2,369 included departmental and other publications for depositories of partial sets and for miscellaneous correspondents.

The number of boxes sent to each country is given in the following table:

Consignments of exchanges for foreign countries.

Country.	Number of boxes.	Country.	Number of boxes.
Argentina.....	58	Jamaica.....	5
Austria.....	99	Japan.....	54
Barbados.....	1	Korea.....	2
Belgium.....	142	Netherlands.....	77
Bolivia.....	8	New South Wales.....	22
Brazil.....	37	New Zealand.....	25
British Colonies.....	25	Nicaragua.....	2
British Guiana.....	5	Norway.....	36
Bulgaria.....	8	Paraguay.....	7
Canada.....	20	Peru.....	16
Chile.....	22	Poland.....	18
China.....	105	Portugal.....	13
Colombia.....	13	Queensland.....	15
Costa Rica.....	11	Salvador.....	2
Cuba.....	5	Siam.....	5
Czechoslovakia.....	194	South Australia.....	16
Denmark.....	32	Spain.....	63
Ecuador.....	9	Sweden.....	58
Egypt.....	9	Switzerland.....	14
Finland.....	16	Tasmania.....	29
France.....	218	Trinidad.....	2
Germany.....	691	Union of South Africa.....	36
Great Britain and Ireland.....	331	Uruguay.....	16
Greece.....	12	Venezuela.....	11
Guatemala.....	2	Victoria.....	30
Honduras.....	2	Western Australia.....	14
Hungary.....	27		
India.....	41	Total.....	2,752
Italy.....	106		

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS.

In accordance with the terms of a convention concluded at Brussels March 15, 1886, and under authority granted by Congress in resolutions approved March 2, 1867, and March 2, 1901, there are now sent through the exchange service regularly to depositories abroad 57 full sets of United States official documents and 39 partial sets—Poland having been added during the year to the list of those countries receiving full sets, and Latvia and the Library of the League of Nations, located in Geneva, Switzerland, to the list of those receiving partial sets. The number of full and partial sets now being sent abroad, it will be seen, is 96. The total number provided by law for the use of the Library of Congress and for international exchange is 100.

The full set of documents sent to Poland is deposited in the Bibliothèque du Ministère des Relations Extérieures, Warsaw. The

partial set for Latvia is deposited in the office of the prime minister at Riga.

I stated last year that it was understood that the Czechoslovak depository would be the Ministère de l'Instruction Publique, at Prague. Information has since been received from the Government of Czechoslovakia to the effect that the United States official documents would be deposited in the Bibliothèque de l'Assemblée Nationale in Prague.

A complete list of the depositories is given below :

DEPOSITORIES OF FULL SETS.

- ARGENTINA: Ministerio de Relaciones Exteriores, Buenos Aires.
 AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.
 AUSTRIA: Statistische Zentral-Kommission, Vienna.
 BADEN: Universitäts-Bibliothek, Freiburg. (Depository of the State of Baden.)
 BAVARIA: Staats-Bibliothek, Munich.
 BELGIUM: Bibliothèque Royale, Brussels.
 BRAZIL: Bibliotheca Nacional, Rio de Janeiro.
 BUENOS AIRES: Biblioteca de la Universidad Nacional de La Plata. (Depository of the Province of Buenos Aires.)
 CANADA: Library of Parliament, Ottawa.
 CHILE: Biblioteca del Congreso Nacional, Santiago.
 CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
 COLOMBIA: Biblioteca Nacional, Bogotá.
 COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
 CUBA: Secretaría de Estado (Asuntos Generales y Canje Internacional) Habana.
 CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.
 DENMARK: Kongelige Bibliotheket, Copenhagen.
 ENGLAND: British Museum, London.
 FRANCE: Bibliothèque Nationale, Paris.
 GERMANY: Deutsche Reichstags-Bibliothek, Berlin.
 GLASGOW: City Librarian, Mitchell Library, Glasgow.
 GREECE: Bibliothèque Nationale, Athens.
 HAITI: Secrétaire d'État des Relations Extérieures, Port au Prince.
 HUNGARY: Hungarian House of Delegates, Budapest.
 INDIA: Imperial Library, Calcutta.
 IRELAND: National Library of Ireland, Dublin.
 ITALY: Biblioteca Nazionale Vittorio Emanuele, Rome.
 JAPAN: Imperial Library of Japan, Tokyo.
 LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
 MANITOBA: Provincial Library, Winnipeg.
 MEXICO: Instituto Bibliográfico, Biblioteca Nacional, Mexico.
 NETHERLANDS: Bibliotheek van de Staten-Generaal, The Hague.
 NEW SOUTH WALES: Public Library of New South Wales, Sydney.
 NEW ZEALAND: General Assembly Library, Wellington.
 NORWAY: Stortingets Bibliothek, Christiania.
 ONTARIO: Legislative Library, Toronto.
 PARIS: Préfecture de la Seine.
 PERU: Biblioteca Nacional, Lima.

POLAND: Bibliothèque du Ministère des Relations Extérieures, Warsaw.
 PORTUGAL: Bibliotheca Nacional, Lisbon.
 PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
 QUEBEC: Library of the Legislature of the Province of Quebec, Quebec.
 QUEENSLAND: Parliamentary Library, Brisbane.
 RUSSIA: Public Library, Petrograd.
 SAXONY: Oeffentliche Bibliothek, Dresden.
 SERBIA: Section Administrative du Ministère des Affaires Étrangères, Belgrade.
 SOUTH AUSTRALIA: Parliamentary Library, Adelaide.
 SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
 SWEDEN: Kungliga Biblioteket, Stockholm.
 SWITZERLAND: Bibliothèque Fédérale Centrale, Berne.
 TASMANIA: Parliamentary Library, Hobart.
 TURKEY: Department of Public Instruction, Constantinople.
 UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
 URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
 VENEZUELA: Biblioteca Nacional, Caracas.
 VICTORIA: Public Library of Victoria, Melbourne.
 WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
 WURTEMBERG: Landesbibliothek, Stuttgart.

DEPOSITORIES OF PARTIAL SETS.

ALBERTA: Provincial Library, Edmonton.
 ALSACE-LORRAINE: Bibliothèque Universitaire et Régionale de Strasbourg, Strasbourg.
 BOLIVIA: Ministerio de Colonización y Agricultura, La Paz.
 BRAZIL: Bibliotheca da Assembleia Legislativa do Estado do Rio de Janeiro, Niteroy.
 BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
 BRITISH COLUMBIA: Legislative Library, Victoria.
 BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
 BULGARIA: Ministère des Affaires Étrangères, Sofia.
 CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.
 ECUADOR: Biblioteca Nacional, Quito.
 EGYPT: Bibliothèque Khédiviale, Cairo.
 FINLAND: Central Library of the State, Helsingfors.
 GUATEMALA: Secretary of the Government, Guatemala.
 HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
 HESSE: Landesbibliothek, Darmstadt.
 HONDURAS: Secretary of the Government, Tegucigalpa.
 JAMAICA: Colonial Secretary, Kingston.
 LATVIA: Office of the Prime Minister, Riga.
 LIBERIA: Department of State, Monrovia.
 LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
 LÜBECK: President of the Senate.
 MADRAS, PROVINCE OF: Chief Secretary to the Government of Madras, Public Department, Madras.
 MALTA: Lieutenant Governor, Valetta.
 MONTENEGRO: Ministère des Affaires Étrangères, Cetinje.
 NEW BRUNSWICK: Legislative Library, Fredericton.
 NEWFOUNDLAND: Colonial Secretary, St. John's.
 NICARAGUA: Superintendente de Archivos Nacionales, Managua.

NORTHWEST TERRITORIES: Government Library, Regina.

NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.

PANAMA: Secretaría de Relaciones Exteriores, Panama.

PARAGUAY: Oficina General de Inmigracion, Asuncion.

PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.

ROUMANIA: Academia Romana, Bucharest.

SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

SIAM: Department of Foreign Affairs, Bangkok.

STRAITS SETTLEMENTS: Colonial Secretary, Singapore.

SWITZERLAND: Library of the League of Nations, Palace of Nations, Quai de Lemán, Geneva.

UNITED PROVINCES OF AGRA AND OUDH: Undersecretary to Government, Allahabad.

VIENNA: Bürgermeister-Amt der Stadt, Wien.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNALS.

The interparliamentary exchange is separate and distinct from the exchange of official documents referred to above and is carried on by this Institution in behalf of the United States Government in accordance with authority granted in a resolution of Congress approved March 4, 1909, the purpose of that resolution being to carry into effect the provisions of the second convention, concluded at Brussels March 15, 1886, providing for the immediate exchange of the official journal as well as of the parliamentary annals and documents, to which the United States was one of the signatories.

While the Government of Poland has not signified its adherence to the above-mentioned convention, it has entered into the immediate exchange with the United States.

A complete list of the countries now taking part in this exchange is given below, together with the names of the establishments to which the daily issue of the Congressional Record is forwarded:

ARGENTINA: Biblioteca del Congreso Nacional, Buenos Aires.

AUSTRALIA: Library of the Commonwealth Parliament, Melbourne.

AUSTRIA: Bibliothek des Nationalrates, Wien I.

BADEN: Universitäts-Bibliothek, Heidelberg.

BELGIUM: Bibliothèque de la Chambre des Représentants, Brussels.

BOLIVIA: Cámara de Diputados, Congreso Nacional, La Paz.

BRAZIL: Bibliotheca do Congresso Nacional, Rio de Janeiro.

BUENOS AIRES: Biblioteca del Senado de la Provincia de Buenos Aires, La Plata.

CANADA:

Library of Parliament, Ottawa.

Clerk of the Senate, Houses of Parliament, Ottawa.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA:

Biblioteca de la Cámara de Representantes, Habana.

Biblioteca del Senado, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DENMARK: Rigsdagens Bureau, København.

FRANCE:

Bibliothèque de la Chambre des Députés, au Palais Bourbon, Paris.

Bibliothèque du Sénat, au Palais du Luxembourg, Paris.

GREAT BRITAIN: Library of the Foreign Office, Downing Street, London, S. W. 1.

GREECE: Library of Parliament, Athens.

GUATEMALA: Biblioteca de la Oficina Internacional Centro-Americana, Sa Calle Poniente No. 1, Ciudad de Guatemala.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

HUNGARY: Bibliothek des Abgeordnetenhausen, Budapest.

ITALY:

Biblioteca della Camera dei Deputati, Palazzo di Monte Citorio, Rome.

Biblioteca del Senato del Regno, Palazzo Madama, Rome.

LIBERIA: Department of State, Monrovia.

JUGOSLAVIA: Library of the Skupstina, Belgrade.

NEW SOUTH WALES: Library of Parliament, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

PERU: Cámara de Diputados, Congreso Nacional, Lima.

POLAND: Ministère des Affairs Etrangères, Warsaw.

PORTUGAL: Bibliotheca das Cortes, Lisbon.

PRUSSIA: Bibliothek des Abgeordnetenhausen, Prinz-Albrechtstrasse 5, Berlin, S. W. 11.

QUEENSLAND: The Chief Secretary's Office, Brisbane.

ROUMANIA: Bibliothèque de la Chambre des Députés, Bucharest.

RUSSIA: Sendings temporarily suspended.

SPAIN:

Biblioteca del Congreso de los Diputados, Madrid.

Biblioteca del Senado, Madrid.

SWITZERLAND: Bibliothèque de l'Assemblée Fédérale Suisse, Berne.

TRANSVAAL: State Library, Pretoria.

UNION OF SOUTH AFRICA: Library of Parliament, Cape Town.

URUGUAY: Biblioteca de la Cámara de Representantes, Montevideo.

VENEZUELA: Cámara de Diputados, Congreso Nacional, Caracas.

WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.

It will be noted from the above list that there are at present 38 different foreign States or Provinces with which the immediate exchange of the official journal is carried on. To some two copies of the Congressional Record are forwarded—one to the Upper and one to the Lower House of Parliament—the total number transmitted being 43. The number provided by law for this exchange is limited to 100.

FOREIGN EXCHANGE AGENCIES.

Agencies have been established during the year by the Governments of Danzig and Poland. Shipments to Czechoslovakia were inaugurated last year, consignments being sent to the Ministère de l'Instruction Publique. The Czechoslovak Government has since established an international exchange service under the direction of the Bibliothèque de l'Assemblée Nationale.

A complete list of the foreign exchange agencies or bureaus is given below:

ALGERIA, *via* France.

ANGOLA, *via* Portugal.

- ARGENTINA: Comisión Protectora de Bibliotecas Populares, Lavalle 1216, Buenos Aires.
- AUSTRIA: Statistische Zentral-Kommission, Vienna.
- AZORES, *via* Portugal.
- BELGIUM: Service Belge des Échanges Internationaux, Rue des Longs-Chariots 46, Brussels.
- BOLIVIA: Oficina Nacional de Estadística, La Paz.
- BRAZIL: Serviço de Permutações Internacionais, Bibliotheca Nacional, Rio de Janeiro.
- BRITISH COLONIES: Crown Agents for the Colonies, London.
- BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.
- BRITISH HONDURAS: Colonial Secretary, Belize.
- BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.
- CANARY ISLANDS, *via* Spain.
- CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.
- CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
- COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.
- COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
- CZECHOSLOVAKIA: Service Tchécoslovaque des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1-79.
- DANZIG: Stadtbibliothek, Danzig.
- DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
- DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.
- ECUADOR: Ministerio de Relaciones Exteriores, Quito.
- EGYPT: Government Publications Office, Printing Department, Bulaq, Cairo.
- FINLAND: Delegation of the Scientific Societies of Finland, Helsingfors.
- FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.
- GERMANY: Amerika-Institut, Universitätsstrasse 8, Berlin, N. W. 7.
- GREAT BRITAIN AND IRELAND: Messrs. Wheldon & Wesley, 28 Essex Street, Strand, London.
- GREECE: Bibliothèque Nationale, Athens.
- GREENLAND, *via* Denmark.
- GUADELOUPE, *via* France.
- GUATEMALA: Instituto Nacional de Varones, Guatemala.
- GUINEA, *via* Portugal.
- HAITI: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
- HONDURAS: Biblioteca Nacional, Tegucigalpa.
- HUNGARY: Dr. Julius Pikler, Fővárosi Telekértéknnylvántartó Hivatal (City Land Valuation Office), Központi Városház, Budapest IV.
- ICELAND, *via* Denmark.
- INDIA: Superintendent of Stationery, Bombay.
- ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
- JAMAICA: Institute of Jamaica, Kingston.
- JAPAN: Imperial Library of Japan, Tokyo.
- JAVA, *via* Netherlands.
- KOREA: Government General, Keijo.
- LIBERIA: Bureau of Exchanges, Department of State, Monrovia.
- LORENÇO MARQUEZ: Government Library, Lourenço Marquez.
- LUXEMBURG, *via* Germany.

MADAGASCAR, *via* France.

MADEIRA, *via* Portugal.

MOZAMBIQUE, *via* Portugal.

NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Académie technique, Delft.

NEW GUINEA, *via* Netherlands.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: Dominion Museum, Wellington.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

NORWAY: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.

PANAMA: Secretaria de Relaciones Exteriores, Panama.

PARAGUAY: Servicio de Canje Internacional de Publicaciones, Sección Consular y de Comercio, Ministerio de Relaciones Exteriores, Asuncion.

PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.

POLAND: Bibliothèque du Ministère des Relations Extérieures, Warsaw.

PORTUGAL: Secção de Trocas Internacionais, Bibliotheca Nacional, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

ROUMANIA: Shipments temporarily suspended.

RUSSIA: Shipments temporarily suspended.

SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

SIAM: Department of Foreign Affairs, Bangkok.

SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.

SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.

SUMATRA, *via* Netherlands.

SWEDEN: Kongliga Svenska Vetenskaps Akademien, Stockholm.

SWITZERLAND: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.

SYRIA: American University of Beirut.

TASMANIA: Secretary to the Premier, Hobart.

TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.

TUNIS, *via* France.

TURKEY: Shipments temporarily suspended.

UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.

URUGUAY: Oficina de Canje Internacional, Montevideo.

VENEZUELA: Biblioteca Nacional, Caracas.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

WINDWARD AND LEEWARD ISLANDS: Imperial Department of Agriculture, Bridgetown, Barbados.

In conclusion, I beg to express my appreciation of the conscientious attention to duty by the employees of the Exchange Office, without which it would not have been possible to handle the large volume of work passing through the service during the year.

Respectfully submitted.

C. G. ABBOT,

Assistant Secretary,

In Charge of Library and Exchanges.

Dr. CHARLES D. WALCOTT,

Secretary of the Smithsonian Institution.

APPENDIX 6.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to present the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1921:

The appropriations allowed by Congress in the sundry civil act included \$125,000 for the regular maintenance of the park, \$80,000 for the purchase of additional land, and \$200 for miscellaneous printing and binding.

Prices on almost all necessary supplies remained high during the early months of the year and, as a consequence, only very limited funds were available for repairs or permanent improvements. In the later months there was a decided drop in the prices of several items of food for animals, and particularly in forage, so that a few long-delayed repairs and improvements, some of them begun five years ago but discontinued for lack of funds, could be undertaken.

The number of animals on exhibition is greater than at any period since 1912; the number of species represented is greater than ever before; and the scientific importance and actual monetary value of the collections far exceed any previous year in the history of the park. A new record for attendance was also reached, due in a measure to the recent rapid development of near-by residential sections, but in a greater measure due to increased interest by the public in the animal collections and in the recreational features offered by such an establishment.

ACCESSIONS.

Gifts.—An unusual number of animals were added to the collection as gifts, or were placed by friends of the park on indefinite deposit. The total number of specimens received in this manner was 178, and the donations included numerous rare and important species.

Mr. Isaac Ellison, of Singapore, presented to the park a fine young male orang-utan, about $3\frac{1}{2}$ years old. No specimen of this ape had been on exhibition in Washington for many years, and the addition to the collection of an example so thrifty is gratifying. Mr. Ellison brought the orang-utan, together with a Javan macaque, with him from Singapore, while on a visit to America.

The Canadian Government, through Mr. J. B. Harkin, Commissioner of Dominion Parks, presented four mountain goats and two

Rocky Mountain sheep, all captured in the Rocky Mountains Park and shipped from Banff, Alberta. The sheep, both ewes, are most welcome additions to the small herd received from the same source in 1917, which has done so well in our paddocks. The mountain goats are the first on exhibition here in many years, and in the large range prepared especially for them have attracted great attention. A young male, born here May 20, 1921, appears to be a thrifty animal.

Mr. Victor J. Evans, of Washington, D. C., who has for many years taken great interest in the National Zoological Park, and has, from time to time, added many rare and unusual animals to the collection, presented during the year a young male Kadiak bear, a pair of Count Raggi's birds of paradise, and some valuable parrots. The bear gives promise of becoming an exceptionally large individual, and no species of bird of paradise has before been shown in the park.

Four shipments from tropical America added, by gift, a number of species new to the collections. Dr. F. W. Goding, American consul general at Guayaquil, Ecuador, transmitted specimens of the giant Galapagos tortoise, one each from Albemarle Island and Indefatigable Island. The Indefatigable Island species is very rare and had never before been on exhibition. Hon. Henry D. Baker, American consul at Trinidad, British West Indies, sent specimens of the Trinidad brocket deer and agouti. Mr. Stuart H. Gillmore and Mr. Walter C. B. Morse, of Washington, brought with them from Surinam a small collection of animals, including specimens of the golden-hooded oriole and weeping capuchin. Dr. Paul Bartsch, of the National Museum, collected and presented four large ground iguanas from Andros Island and an additional specimen of the great white heron from the Florida Keys.

Mr. A. K. Haagner, director of the zoological garden at Pretoria, South Africa, brought to America, as a gift to the park, a specimen of his recently discovered Rhodesian baboon.

Seventy-two individual donors contributed to the collection during the year. The complete list is as follows:

Mr. H. E. Allen, Washington, D. C., red-and-blue-and-yellow macaw.

Dr. Wade H. Atkinson, Washington, D. C., Virginia opossum.

Mr. Carl Aylor, Washington, D. C., screech owl.

Miss Henriette A. Bagnell, Washington, D. C., two grass paroquets.

Hon. Henry D. Baker, Trinidad, British West Indies, Trinidad brocket and two Trinidad agoutis.

Dr. Paul Bartsch, Washington, D. C., white heron and four ground iguanas.

Miss Dorothy Beers, Washington, D. C., alligator.

Mr. Harmon B. Bell, jr., Ruxton, Md., alligator.

Mr. I. E. Bennett, West Palm Beach, Fla., laughing gull.

Mr. K. M. Bradshaw, Bristow, Va., barn owl.

Ensign Richard H. Brazeal, U. S. S. *Penguin*, San Francisco, Calif., Panama agouti.

Mr. F. W. Briggs, Bristow, Va., great horned owl.

Miss G. R. Brigham, Washington, D. C., red-billed hill-tit.

Cafisch Lumber Co., Albright, W. Va., banded rattlesnake, copperhead, and blacksnake.

Mr. Jas. E. Cameron, Washington, D. C., red fox.

Canadian Government, through Hon. J. B. Harkin, two Rocky Mountain sheep and four mountain goats.

Mr. W. B. Carpenter, Washington, D. C., red-billed hill-tit, two Gouldian finches, two canaries, and two grass paroquets.

Mr. Milton Curtis, St. David, Ariz., Gila monster.

Mr. James Y. Davis, Washington, D. C., sparrowhawk.

Mr. E. B. Dewey, Washington, D. C., sparrowhawk.

Mr. Elaine Elkins, Washington, D. C., two raccoons.

Mr. Ernest B. Ellis, Millboro, N. C., horned toad.

Mr. Isaac Ellison, Singapore, Straits Settlements, orang-utan and Javan macaque.

Mr. Louis C. Etchison, Jefferson, Md., red-tailed hawk and barn owl.

Mr. Victor J. Evans, Washington, D. C., Kadiak bear, king paroquet, red-sided eucalyptus parrot, and two Count Raggi's birds of paradise.

Mr. Arthur H. Fisher, Washington, D. C., coach-whip snake and spreading adder.

Mr. H. B. Fisher, Takoma Park, Md., mourning dove.

Mr. Stuart H. Gillmore and Mr. Walter C. B. Morse, Washington, D. C., coati mundi, capuchin monkey, yellow-rumped agouti, and golden-hooded oriole.

Dr. Frederick W. Goding, Guayaquil, Ecuador, two Galapagos tortoises.

Mr. Leonard C. Gunnell, Washington, D. C., woodcock.

Mr. A. K. Haagner, Pretoria, South Africa, Rhodesian baboon.

Mrs. E. B. Harden, Washington, D. C., three horned toads.

Hon. Warren G. Harding, White House, Washington, D. C., Alaskan bald eagle.

Mrs. E. P. Hopkins, Washington, D. C., two canaries.

Mrs. John F. Hord, Washington, D. C., grass paroquet, red-billed weaver, nutmeg finch, European goldfinch, two strawberry finches, two black-headed finches, three Java finches, four canaries, and seven bengalees.

Mr. L. M. Humphrey, Glen Echo, Md., pilot blacksnake.

Miss May E. Irish, Hillside, Me., duck hawk.

Mrs. H. S. Johnson, Washington, D. C., canary.

Mr. Ellis S. Joseph, Sydney, Australia, sulphur-crested cockatoo and four red-rumped paroquets.

Maj. Howard C. Judson, United States Marine Corps, Washington, D. C., red-crowned parrot and yellow-cheeked parrot.

Mr. Charles R. Kengla, Washington, D. C., great horned owl.

Mr. J. C. Lindsey, Clarendon, Va., ringed turtle dove.

Mrs. L. D. Lunt, Landover, Md., alligator.

Mr. George Marshall, Laurel, Md., garter snake and blacksnake.

Mrs. W. S. Moore, Washington, D. C., tovi paroquet.

Dr. F. H. Morhart, Washington, D. C., raccoon.

Mrs. Louis Nulton, Winchester, Va., two marmosets.

Mr. L. C. Painter, Alexandria, Va., three red-shouldered hawks.

Miss Mary Dixon Palmer, Washington, D. C., alligator.

Pan American Union, Washington, D. C., 16 alligators.

Mr. L. V. Pearson, Washington, D. C., red-tailed hawk.

Mr. Jack Polkinhorn, Washington, D. C., painted turtle.

Mrs. N. C. Reid, Cristobal, Canal Zone, Panama deer.

Mrs. E. T. Ryan, Washington, D. C., canary.
 Mr. Edw. S. Schmid, Washington, D. C., blacksnake and two skunks.
 Dr. R. W. Shufeldt, Washington, D. C., box tortoise, ground rattlesnake, two king snakes, and two wood turtles.
 Mr. Lubert Sisco, Washington, D. C., pilot blacksnake.
 Mr. H. N. Slater, New York, N. Y., East African baboon.
 Mr. G. T. Smallwood, Washington, D. C., 15 opossums
 Mr. Albert Stabler, Washington, D. C., barred owl.
 Mr. Robert M. Stabler, Washington, D. C., five Virginia opossums.
 Mrs. Ida Stanley, Washington, D. C., raccoon.
 Mr. J. F. Steffey, Fort Washington, Md., great horned owl.
 Mr. Arthur Tew, Washington, D. C., alligator.
 Mrs. E. F. Townsend, Washington, D. C., alligator.
 Mrs. Russell Tyson, Brattleboro, Vt., albino woodchuck.
 Mr. Titus Ulke, Washington, D. C., painted turtle and milk snake.
 Mr. F. L. Van Patten, Great Falls, Va., barred owl.
 Mrs. O. D. Wayland, Washington, D. C., canary.
 Mr. J. T. Wenchel, Takoma Park, Md., rabbit.
 Mr. Ira Cartright Wetherill, Machadoc, Va., diamond-back terrapin.
 Mr. Allen H. Whisner, Washington, D. C., fox squirrel.

Births.—Fifty-five mammals were born and 21 birds were hatched in the park during the year. As usual, these records include only such as are reared to a reasonable age, no account being made in these published statistics of young that live only a few days. The births include: European brown bear, 4; dingo, 2; great gray kangaroo, 1; red kangaroo, 3; black-tailed wallaby, 2; rufous-bellied wallaby, 1; brush-tailed rock wallaby, 1; Australian opossum, 1; rhesus monkey, 4; mona, 1; mountain goat, 1; Rocky Mountain sheep, 1; Indian antelope, 2; American bison, 3; llama, 3; guanaco, 1; Virginia deer, 4; black-tailed deer, 3; fallow deer, 1; Japanese deer, 3; hog deer, 3; barasingha, 2; red deer, 6; American elk, 2. Birds hatched were of the following species: White ibis, American coot, wood duck, canary, and peafowl.

Exchanges.—There were received during the year, in exchange for surplus stock, 57 mammals, 152 birds, and 6 reptiles. The most important of these accessions were a large collection of Australasian birds from Mr. E. S. Joseph, the well-known animal dealer of Sydney, Australia, and a collection of African mammals from Mr. A. K. Haagner, Pretoria, South Africa. Among the birds received from Mr. Joseph are such desirable species as the pied goose, Eyton's tree duck, Australian black duck, Pacific gull, white-bellied sea eagle, golden-shouldered paroquet, and satin bower-bird. African mammals included in the exchange from Mr. Haagner were a lechwe antelope, 2 blesboks, a springbok, an African porcupine, a chacma baboon, and a specimen of Wahlberg's mongoose. Other valuable mammals received in exchange from miscellaneous sources are 2 Barbary apes from Gibraltar, white-collared, black, and sooty mangabeys, an

Arabian baboon, 2 ruffed lemurs, 2 Malay porcupines, 2 palm civets, and a Florida manatee.

The birds received in exchange include also 2 sun-bitterns, 2 black-necked swans, 2 Cape Barren geese, 4 upland geese, an Indian jabiru, a sarus crane, scarlet ibis, yellow-wattled lapwing, and numerous small birds of various kinds. Five tree iguanas and a large boa constrictor were received from South America.

Purchases.—Only 9 mammals, 45 birds, and 9 reptiles were purchased during the year, as the limited funds available would not permit of much expenditure for stock. The mammals purchased were 4 armadillos, 2 gray foxes, a Florida lynx, a pigtailed monkey, and one bandicoot. Birds purchased were mostly hawks, owls, and waterfowl at low cost, but some exceptionally valuable specimens were also obtained. A specimen of the rare kagu from New Caledonia Island, and of the Nepalese paroquet from India, represent species new to the collection.

Transfers.—The Biological Survey of the Department of Agriculture continued its contributions to the collection. Two young pumas or mountain lions from the Kaibab Forest, Utah, through Mr. George E. Holman; and three young pumas from Arizona, through Mr. M. E. Musgrave, were among the most valuable transfers from the survey. Mr. Vernon Bailey, chief field naturalist, contributed an interesting collection of small mammals, including various species of pocket mice, kangaroo rats, spermophiles, and other rodents. Two little brown cranes from Nebraska were also transferred from field agents of the Biological Survey.

Captured in the park.—Five birds and 2 reptiles, captured within the National Zoological Park, were added to the collection.

Deposited.—A few parrots and other birds and one reptile, needed for exhibition, were accepted on deposit. Owing to the greatly increased work at the park and the small force of keepers employed to care for the growing collections, it has been necessary to refuse birds and mammals offered on deposit, and subject to recall by the owner, unless the specimens represent species which add distinctly to the exhibition value of the collection.

REMOVALS.

Surplus animals sent away in exchange for other stock during the year included 62 mammals, 45 birds, and 12 reptiles. Most of the surplus animals were born in the park. Among the specimens so exchanged were a young hippopotamus, 5 American bison, 1 yak, 1 East African cland, 1 Indian antelope, 4 llamas, 2 American elk, 11 European red deer, 2 Japanese deer, 2 red kangaroos, 2 European brown bears, 2 African lions, 1 mountain lion, 4 gray foxes, 2 wolves,

2 coypus, 3 rhesus monkeys, a number of waterfowl, peafowl, and other birds, and 12 alligators.

A number of animals on deposit were returned to owners.

The death rate remains very low; for mammals and birds about as in the past four years; for reptiles much lower. Among the most serious losses of mammals long in the collection must be mentioned the death of the vicuña (*Lama vicugna*) from enteritis on September 7, 1920. This animal was received at the park on November 24, 1908, and thus had been in the collection nearly 12 years. A female zebu (*Bos indicus*), received when about 3 years old, on April 11, 1899, died on March 25, 1921, only a few days under 22 years from date of arrival. A male American elk, born in the park May 31, 1910, died November 5, 1920. The male Kenai Peninsula black bear (*Ursus americanus perniger*), received when a cub of about 2 years of age, March 5, 1903, died of internal hemorrhage, June 23, 1921, after 18 years and 3 months in the park. A coyote (*Canis lutrans*), received April 26, 1906, died September 28, 1920; a paca (*Cuniculus paca*), received April 11, 1908, died January 3, 1921, of acute congestion of the lungs; and a brown macaque (*Macaca speciosa*), received July 30, 1910, died of gastroenteritis on November 26, 1920.

Three birds with long records were lost during the year. A red-and-blue macaw (*Ara chloroptera*), received as a gift from the governor of the State of Para, Brazil, August 7, 1899, died nearly 21 years later, on July 3, 1920. A yellow-shouldered parrot (*Amazona barbadensis*), received from Hon. E. H. Plumacher, American consul at Maracaibo, Venezuela, September 10, 1902, died on January 26, 1921; and a demoiselle crane, received July 2, 1903, died on June 18, 1921.

Other serious losses were a female bison, died of metritis, July 7, 1920; a male llama, acute congestion of lungs, July 25, 1920; and a male prong-horned antelope, anemia, October 13, 1920.

Post-mortem examinations were made by the pathological division of the Bureau of Animal Industry, and, in four cases, by the Army Medical Museum. The following list shows the results of autopsies, the cases being arranged by groups:

CAUSES OF DEATH.

MAMMALS.

Marsupialia: Tuberculosis, 2; congestion of lungs, 1; pleurisy and pericarditis, 1; enteritis, 1; peritonitis, 1; pyemia, 1; septicemia, 1.

Carnivora: Pneumonia, 2; tuberculosis, 1; gastroenteritis, 2; internal hemorrhage, 3; leukemia, 1.

Rodentia: Congestion of lungs, 1.

Primates: Tuberculosis, 5; enteritis, 5; gastroenteritis, 2; colitis, 1; echinococcus infestation, 1; cage paralysis, 1.

Artiodactyla: Pneumonia, 1; verminous broncho-pneumonia, 1; tuberculosis, 1; congestion of lungs, 1; enteritis, 2; gastritis, 1; gastroenteritis, 1; metritis, 1; anemia, 3; accident, 1.

BIRDS.

Ciconiiformes: Impaction of stomach, 1; anemia, 1; septicemia, 2; no cause found, 3.

Anseriformes: Pneumonia, 1; enteritis, 2; no cause found, 3.

Falconiformes: No cause found, 1.

Galliformes: Tuberculosis, 1; aspergillosis, 2; enteritis, 3; coccidiosis, 6; wry-neck, 1; no cause found, 2.

Gruiformes: Aspergillosis, 1; enteritis, 1; no cause found, 2.

Charadriiformes: Tuberculosis, 1; enteritis, 1; internal hemorrhage, 1.

Psittaciformes: Enteritis, 3; anemia, 1; internal hemorrhage, 1.

Coraciiformes: Enteritis, 1; abdominal tumor and enteritis, 1.

Passeriformes: Enteritis, 6.

REPTILES.

Serpentes: Pneumonia, 1; no cause found, 1.

Thirty-two specimens of special scientific importance, or needed for exhibition purposes, were transferred after death to the United States National Museum. These included 16 mammals, 11 birds, and 5 reptiles. Four specimens of mammals, desired for anatomical work, were sent to the Army Medical Museum. The skins of 17 birds were added to the reference collection of "dealers' cage birds" in the office of the superintendent, National Zoological Park.

ANIMALS IN THE COLLECTION JUNE 30, 1921.

MAMMALS.

MARSUPIALIA.		CARNIVORA.	
Virginia opossum (<i>Didelphis virginiana</i>)	18	Kadiak bear (<i>Ursus middendorffi</i>)	2
Tasmanian devil (<i>Sarcophilus harrisii</i>)	2	Alaska Peninsula bear (<i>Ursus gyas</i>)	2
Australian opossum (<i>Trichosurus vulpecula</i>)	2	Yakutat bear (<i>Ursus dalli</i>)	1
Dnsky phalanger (<i>Trichosurus fuliginosus</i>)	1	Kidder's bear (<i>Ursus kidderi</i>)	2
Flying phalanger (<i>Petaurus breviceps</i>)	8	European bear (<i>Ursus arctos</i>)	6
Brush-tailed rock wallaby (<i>Petrogale penicillata</i>)	4	Grizzly bear (<i>Ursus horribilis</i>)	2
Rufous-bellied wallaby (<i>Macropus bulbacanthi</i>)	6	Apache grizzly (<i>Ursus apache</i>)	1
Parma wallaby (<i>Macropus parma</i>)	1	Himalayan bear (<i>Ursus thibetanus</i>)	1
Black-tailed wallaby (<i>Macropus bicolor</i>)	3	Black bear (<i>Ursus americanus</i>)	1
Great gray kangaroo (<i>Macropus giganteus</i>)	2	Cinnamon bear (<i>Ursus americanus cinnamonomum</i>)	2
Black faced kangaroo (<i>Macropus melanops</i>)	2	Florida bear (<i>Ursus floridanus</i>)	2
Wallaroo (<i>Macropus robustus</i>)	2	Glacier bear (<i>Ursus emmonsii</i>)	1
Red kangaroo (<i>Macropus rufus</i>)	8	Sun bear (<i>Helarctos malayanus</i>)	1
		Sloth bear (<i>Melarsus ursinus</i>)	1
		Polar bear (<i>Thalarchos maritimus</i>)	2
		Dingo (<i>Canis dingo</i>)	4
		E-kimo dog (<i>Canis familiaris</i>)	2
		Gray wolf (<i>Canis nubilus</i>)	8
		Southern wolf (<i>Canis floridanus</i>)	1
		Woodhouse's wolf (<i>Canis frustrator</i>)	2
		Coyote (<i>Canis latrans</i>)	1

CARNIVORA—Continued.

Red fox (<i>Vulpes fulva</i>)	5
Kit fox (<i>Vulpes velox</i>)	2
Gray fox (<i>Urocyon cinereoargenteus</i>)	4
Cacomistle (<i>Bassariscus astutus</i>)	1
Raccoon (<i>Procyon lotor</i>)	12
Gray coati mundi (<i>Nasua narica</i>)	2
Red coati mundi (<i>Nasua nasua</i>)	2
Kinkajou (<i>Potos flavus</i>)	2
Mexican kinkajou (<i>Potos flavus actucus</i>)	1
Marten (<i>Martes americana</i>)	1
Ferret (<i>Mustela furo</i>)	1
Tayra (<i>Tayra barbara</i>)	1
Skunk (<i>Mephitis nigris</i>)	3
Florida skunk (<i>Mephitis elongata</i>)	2
American badger (<i>Taxidea taxus</i>)	1
European badger (<i>Meles meles</i>)	1
Florida otter (<i>Lutra canadensis vago</i>)	2
Palm civet (<i>Paradoxurus hermaphroditus</i>)	2
Wahlberg's mongoose (<i>Hologale parvula</i>)	1
Spotted hyena (<i>Crocuta crocuta</i>)	1
Striped hyena (<i>Hyena hyena</i>)	2
African cheetah (<i>Acinonyx jubatus</i>)	2
Lion (<i>Felis leo</i>)	2
Bengal tiger (<i>Felis tigris</i>)	1
Manchurian tiger (<i>Felis tigris lenenis</i>)	2
Leopard (<i>Felis pardus</i>)	1
East African leopard (<i>Felis pardus suahelica</i>)	1
Jaguar (<i>Felis onca</i>)	1
Brazilian ocelot (<i>Felis pardalis brasiliensis</i>)	1
Margay cat (<i>Felis tigrina</i>)	1
Snow leopard (<i>Felis uncia</i>)	1
Mexican puma (<i>Felis atrox</i>)	4
Mountain lion (<i>Felis hippestes</i>)	3
Canada lynx (<i>Lynx canadensis</i>)	1
Northern wild cat (<i>Lynx uinta</i>)	3
Bay lynx (<i>Lynx rufus</i>)	2
Florida lynx (<i>Lynx rufus floridanus</i>)	1

PINNIPEDIA.

California sea lion (<i>Zalophus californianus</i>)	2
Harbor seal (<i>Phoca vitulina</i>)	1

RODENTIA.

Woodchuck (<i>Marmota monax</i>)	2
Dusky marmot (<i>Marmota flaviventris obscura</i>)	1
Prairie dog (<i>Cynomys ludovicianus</i>)	5
White-tailed prairie dog (<i>Cynomys gunnisoni</i>)	2
Antelope squirrel (<i>Ammospermophilus leucurus</i>)	1
Arizona antelope squirrel (<i>Ammospermophilus leucurus</i>)	1
Round-tailed spermophile (<i>Citellus tereticaudus</i>)	1
Spotted spermophile (<i>Citellus spilosoma</i>)	1

RODENTIA—Continued.

Honduras squirrel (<i>Sciurus boothi</i>)	1
Fox squirrel (<i>Sciurus niger</i>)	1
Albino squirrel (<i>Sciurus carolinensis</i>)	2
Baird's pocket mouse (<i>Perognathus flavus</i>)	1
Bailey's pocket mouse (<i>Perognathus baileyi</i>)	4
Dusky pocket mouse (<i>Perognathus flavescens perniger</i>)	3
Kangaroo rat (<i>Dipodomys spectabilis</i>)	1
Merriam's kangaroo rat (<i>Dipodomys merriami</i>)	3
Ord's kangaroo rat (<i>Perodipus ordii</i>)	2
American beaver (<i>Castor canadensis</i>)	1
Grasshopper mouse (<i>Onychomys torridus</i>)	3
Gray grasshopper mouse (<i>Onychomys leucogaster fuscogriseus</i>)	1
Montana white-footed mouse (<i>Peromyscus leucopus aridulus</i>)	1
Desert mouse (<i>Peromyscus eremicus</i>)	4
Nebraska white-footed mouse (<i>Peromyscus maniculatus osgoodi</i>)	2
Parasitic mouse (<i>Peromyscus californicus</i>)	1
Wood rat (<i>Neotoma albigula</i>)	2
African porcupine (<i>Hystrix africa australis</i>)	1
Malay porcupine (<i>Acanthion brachyurum</i>)	2
Coypu (<i>Myocastor coypus</i>)	3
Paca (<i>Cuniculus paca</i>)	2
Central American paca (<i>Cuniculus paca virgatus</i>)	1
Mexican agouti (<i>Dasyprocta mexicana</i>)	1
Speckled agouti (<i>Dasyprocta punctata</i>)	2
Panama agouti (<i>Dasyprocta punctata isthmica</i>)	1
Azara's agouti (<i>Dasyprocta azara</i>)	2
Trinidad agouti (<i>Dasyprocta rubrata</i>)	2
Crested agouti (<i>Dasyprocta cristata</i>)	2
Yellow-rumped agouti (<i>Dasyprocta lucifer cayenne</i>)	1
Peruvian guinea pig (<i>Cavia tschudii pallidior</i>)	2
Guinea pig (<i>Cavia porcellus</i>)	20
Capybara (<i>Hydrochærus hydrochæris</i>)	1

LAGOMORPHA.

Domestic rabbit (<i>Oryctolagus cuniculus</i>)	10
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EDENTATA.

Nine-banded armadillo (<i>Dasypus novemcinctus</i>)	2
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PRIMATES.

Ruffed lemur (<i>Lemur variegatus</i>)	2
Black spider monkey (<i>Ateles ater</i>)	1
Gray spider monkey (<i>Ateles Geoffroyi</i>)	1
White-throated capuchin (<i>Cebus capucinus</i>)	4

PRIMATES—Continued.

Weeping capuchin (<i>Cebus apella</i>)	1
Brown capuchin (<i>Cebus fatuellus</i>)	1
Margarita capuchin (<i>Cebus margaritæ</i>)	1
Marmoset (<i>Callithrix jacchus</i>)	2
Chacma (<i>Papio porcus</i>)	2
Rhodesian baboon (<i>Papio rhodesiæ</i>)	1
Hamadryas baboon (<i>Papio hamadryas</i>)	1
East African baboon (<i>Papio ibeanus</i>)	1
Mandrill (<i>Papio sphinx</i>)	1
Drill (<i>Papio leucophaeus</i>)	1
Moor macaque (<i>Cynopithecus maurus</i>)	1
Barbary ape (<i>Simia syriacus</i>)	2
Brown macaque (<i>Macaca speciosa</i>)	1
Pig-tailed monkey (<i>Macaca nemestrina</i>)	1
Burmese macaque (<i>Macaca andamanensis</i>)	1
Rhesus monkey (<i>Macaca rhesus</i>)	29
Bonnet monkey (<i>Macaca sinica</i>)	1
Javan macaque (<i>Macaca mordax</i>)	4
Black mangabey (<i>Cercocebus atterimus</i>)	1
Sooty mangabey (<i>Cercocebus fuliginosus</i>)	2
White-collared mangabey (<i>Cercocebus torquatus</i>)	1
Green guenon (<i>Lasiopyga callitrichus</i>)	2
Vervet guenon (<i>Lasiopyga pygerythra</i>)	1
Mona (<i>Lasiopyga mona</i>)	4
Roloway guenon (<i>Lasiopyga roloway</i>)	1
Patas monkey (<i>Erythrocebus patas</i>)	2
Chimpanzee (<i>Pan troglodytes</i>)	1
Orang-utan (<i>Pongo pygmaeus</i>)	1

ARTIODACTYLA

Wild boar (<i>Sus scrofa</i>)	1
Wart-hog (<i>Phacochoerus aethiopicus</i>)	2
Collared peccary (<i>Pecari angulatus</i>)	1
Hippopotamus (<i>Hippopotamus amphibius</i>)	2
Bactrian camel (<i>Camelus bactrianus</i>)	2
Arabian camel (<i>Camelus dromedarius</i>)	2
Guinea pig (<i>Cavia porcellus</i>)	4
Llama (<i>Lama glama</i>)	7
Alpaca (<i>Lama pacos</i>)	1
Fallow deer (<i>Dama dama</i>)	5
Axis deer (<i>Axis axis</i>)	4
Hog deer (<i>Mylaphus porcinus</i>)	6
Sambur (<i>Rusa unicolor</i>)	2
Barasingha (<i>Rucervus duvaucelii</i>)	9
Burmese deer (<i>Rucervus eldi</i>)	1
Japanese deer (<i>Sika nippon</i>)	12

RATITE.

South African ostrich (<i>Struthio australis</i>)	1
Somali ostrich (<i>Struthio molybdophanes</i>)	1
Rhea (<i>Rhea americana</i>)	2
Sclater's cassowary (<i>Cassidix philipi</i>)	1
Emu (<i>Dromiceus novaehollandiae</i>)	2

ARTIODACTYLA—Continued.

Red deer (<i>Cervus elaphus</i>)	15
Kashmir deer (<i>Cervus hanglu</i>)	2
Bedford deer (<i>Cervus xanthopygus</i>)	6
American elk (<i>Cervus canadensis</i>)	6
Virginia deer (<i>Odocoileus virginianus</i>)	12
Panama deer (<i>Odocoileus chiriquensis</i>)	1
Mule deer (<i>Odocoileus hemionus</i>)	2
Black-tailed deer (<i>Odocoileus columbianus</i>)	5
Trinidad brocket (<i>Mazama simplicicornis</i>)	1
Blesbok (<i>Damaliscus albifrons</i>)	3
White-tailed gnu (<i>Connochaetes gnou</i>)	1
Lechwe (<i>Omotragus lechwe</i>)	1
Indian antelope (<i>Antelope cervicapra</i>)	5
Nilgai (<i>Boselaphus tragocamelus</i>)	2
East African eland (<i>Taurotragus oryx livingstonii</i>)	2
Angora goat (<i>Capra hircus</i>)	1
Tahr (<i>Hemitragus jemlahicus</i>)	3
Mountain goat (<i>Oreamnos americanus</i>)	4
Aoudad (<i>Ammotragus lervia</i>)	1
Rocky Mountain sheep (<i>Ovis canadensis</i>)	6
Arizona mountain sheep (<i>Ovis canadensis guillaudi</i>)	1
Barbados sheep (<i>Ovis aries</i>)	5
Zebu (<i>Bos indicus</i>)	1
Yak (<i>Bocephagus grunniens</i>)	4
American bison (<i>Bison bison</i>)	13
Indian buffalo (<i>Bubalus bubalis</i>)	3

PERISSODACTYLA.

Brazilian tapir (<i>Tapirus terrestris</i>)	2
Mongolian horse (<i>Equus przewalskii</i>)	1
Grant's zebra (<i>Equus burchelli granti</i>)	1
Grevy's zebra (<i>Equus grevyi</i>)	1
Zebra-horse hybrid (<i>Equus grevyi caballus</i>)	1
Zebra-ass hybrid (<i>Equus grevyi asinus</i>)	1

PROTOSCILEA.

Abyssinian elephant (<i>Loxodonta africana oryotis</i>)	1
Sumatran elephant (<i>Elephas sumatranus</i>)	2

SIRENIA.

Florida manatee (<i>Trichechus latirostris</i>)	1
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BIRDS.

CICONIIFORMES.

Water-hen (<i>Ardeotis ardeotis</i>)	4
American white pelican (<i>Pelecanus erythrorhynchos</i>)	7
European white pelican (<i>Pelecanus onocrotalus</i>)	2
Roseate pelican (<i>Pelecanus roseus</i>)	2
Australian pelican (<i>Pelecanus conspicillatus</i>)	2

CICONIIFORMES—Continued.

Brown pelican (<i>Pelecanus occidentalis</i>)	9
Florida cormorant (<i>Phalacrocorax auritus floridanus</i>)	13
Great white heron (<i>Ardea occidentalis</i>)	2
Goliath heron (<i>Ardea goliath</i>)	1
American egret (<i>Cuscmorodius egretta</i>)	3
Snowy egret (<i>Egretta candidissima</i>)	4
Black-crowned night heron (<i>Nycticorax nycticorax naevius</i>)	28
Boatbill (<i>Cochlearius cochlearius</i>)	2
White stork (<i>Ciconia ciconia</i>)	3
Black stork (<i>Ciconia nigra</i>)	1
Indian jabiru (<i>Xenorhynchus asiaticus</i>)	1
Straw-necked ibis (<i>Carphibis spinicollis</i>)	1
Sacred ibis (<i>Threskiornis aethiopicus</i>)	3
Australian ibis (<i>Threskiornis strictipennis</i>)	2
White ibis (<i>Guara alba</i>)	13
Scarlet ibis (<i>Guara rubra</i>)	1
Roseate spoonbill (<i>Ajaia ajaja</i>)	2
European flamingo (<i>Phoenicopterus roseus</i>)	1

ANSERIFORMES.

Mallard (<i>Anas platyrhynchos</i>)	18
East Indian black duck (<i>Anas platyrhynchos</i> var.)	3
Black duck (<i>Anas rubripes</i>)	23
Australian black duck (<i>Anas superciliosa</i>)	4
Gadwall (<i>Chauliasmus streperus</i>)	2
European widgeon (<i>Mareca penelope</i>)	8
Baldpate (<i>Mareca americana</i>)	7
Green-winged teal (<i>Nettion carolinense</i>)	7
European teal (<i>Nettion crecca</i>)	10
Baikal teal (<i>Nettion formosum</i>)	1
Blue-winged teal (<i>Querquedula discors</i>)	6
Garganey (<i>Querquedula querquedula</i>)	1
Cinnamon teal (<i>Querquedula cyanoptera</i>)	1
Shoveller (<i>Spatula clypeata</i>)	4
Pintail (<i>Dafila acuta</i>)	6
Wood duck (<i>Aix sponsa</i>)	15
Mandarin duck (<i>Dendrocygna galericulata</i>)	17
Rufous-crested duck (<i>Netta rufina</i>)	1
Canvas-back (<i>Marila valisineria</i>)	2
Redhead (<i>Marila americana</i>)	8
Ring-necked duck (<i>Marila collaris</i>)	1
Lesser scaup duck (<i>Marila affinis</i>)	9
White-eyed duck (<i>Marila nyroca</i>)	1
Rosy-billed pochard (<i>Metopiana pepasaca</i>)	4
Egyptian goose (<i>Chenalopex aegyptiacus</i>)	2
Upland goose (<i>Chloephaga leucoptera</i>)	2
Snow goose (<i>Chen hyperboreus</i>)	2
Greater snow goose (<i>Chen hyperboreus nivalis</i>)	2
Blue goose (<i>Chen cerulescens</i>)	7

ANSERIFORMES—Continued.

White-fronted goose (<i>Anser albifrons</i>)	3
American white-fronted goose (<i>Anser albifrons gambeli</i>)	3
Bar-headed goose (<i>Eulabeia indica</i>)	1
Canada goose (<i>Branta canadensis</i>)	12
Hutchins's goose (<i>Branta canadensis hutchinsii</i>)	9
Cackling goose (<i>Branta canadensis minima</i>)	2
Brant (<i>Branta bernicla glaucogastra</i>)	11
Barnacle goose (<i>Branta leucopsis</i>)	7
Cape Barren goose (<i>Cereopsis novaehollandiae</i>)	2
Spur-winged goose (<i>Plectropterus gambensis</i>)	2
Pied goose (<i>Anseranas semipalmata</i>)	2
Black-bellied tree duck (<i>Dendrocygna autumnalis</i>)	6
Eyton's tree duck (<i>Dendrocygna eytoni</i>)	4
White-faced tree duck (<i>Dendrocygna viduata</i>)	2
Coscoroba swan (<i>Coscoroba coscoroba</i>)	1
Mute swan (<i>Cygnus gibbus</i>)	3
Whistling swan (<i>Olor columbianus</i>)	1
Trumpeter swan (<i>Olor buccinator</i>)	1
Black swan (<i>Chenopsis atrata</i>)	2

FALCONIFORMES.

South American condor (<i>Vultur gryphus</i>)	1
California condor (<i>Gymnogyps californianus</i>)	3
Turkey vulture (<i>Cathartes aura</i>)	3
Black vulture (<i>Coragyps uruba</i>)	2
King vulture (<i>Sarcorampus papa</i>)	2
Secretary bird (<i>Sagittarius serpentarius</i>)	1
Griffon vulture (<i>Gyps fulvus</i>)	1
Cinereous vulture (<i>Agypsus monachus</i>)	2
Caracara (<i>Polyborus cheriway</i>)	2
Wedge-tailed eagle (<i>Uroaetus audax</i>)	2
Golden eagle (<i>Aquila chrysaetus</i>)	3
White-bellied sea eagle (<i>Circus leucogaster</i>)	2
Bald eagle (<i>Haliaeetus leuccephalus</i>)	11
Alaskan bald eagle (<i>Haliaeetus leuccephalus alascanus</i>)	2
Broad-winged hawk (<i>Buteo platypterus</i>)	1
Red-tailed hawk (<i>Buteo borealis</i>)	6
Red-shouldered hawk (<i>Buteo lineatus</i>)	3
Sparrow hawk (<i>Falco sparverius</i>)	4
Duck hawk (<i>Falco peregrinus anatum</i>)	1

GALLIFORMES.

Razor-billed curassow (<i>Mitu mitu</i>)	1
Wild turkey (<i>Meleagris gallopavo silvestris</i>)	1
Peafowl (<i>Pavo cristatus</i>)	41
Peacock pheasant (<i>Polyplectron bicalcaratum</i>)	1
Silver pheasant (<i>Gallus nythymerus</i>)	1

GALLIFORMES—Continued.

Ring-necked pheasant (<i>Phasianus torquatus</i>)	2
Bobwhite (<i>Colinus virginianus</i>)	1
Gambel's quail (<i>Lophortyx gambelii</i>)	3
Valley quail (<i>Lophortyx californica vallicola</i>)	2

GRUIFORMES.

East Indian gallinule (<i>Porphyrio erythrogastrus</i>)	5
American coot (<i>Fulica americana</i>)	2
South Island weka rail (<i>Ocydromus australis</i>)	3
Short-winged weka (<i>Ocydromus brevialatus</i>)	2
Earl's weka (<i>Ocydromus earlii</i>)	1
Whooping crane (<i>Grus americana</i>)	1
Sandhill crane (<i>Grus mexicana</i>)	2
Little brown crane (<i>Grus canadensis</i>)	6
White-necked crane (<i>Grus leucocervix</i>)	1
Indian white crane (<i>Grus leucogeranus</i>)	2
Lilford's crane (<i>Grus lilfordi</i>)	1
Sarus crane (<i>Grus collaris</i>)	1
Australian crane (<i>Grus rubicunda</i>)	2
Demoiselle crane (<i>Anthropoides virgo</i>)	4
Crowned crane (<i>Balearia patonina</i>)	1
White-backed trumpeter (<i>Psephenops trichoptera</i>)	1
Cariamã (<i>Cariamã cristata</i>)	1
Kagu (<i>Rhynochetos jubatus</i>)	1

CHARADRIIFORMES.

Yellow-wattled lapwing (<i>Lobivanellus indicus</i>)	1
Pacific gull (<i>Gabianus pacificus</i>)	2
Great black-backed gull (<i>Larus marinus</i>)	1
Herring gull (<i>Larus argentatus</i>)	4
Laughing gull (<i>Larus atricilla</i>)	3
Australian crested pigeon (<i>Ocyphaps lophotes</i>)	5
Bronze-wing pigeon (<i>Phaps chalcoptera</i>)	2
Wonga-wonga pigeon (<i>Leucosarcia picta</i>)	6
Wood pigeon (<i>Columba palumbus</i>)	7
Mourning dove (<i>Zenaidura macroura</i>)	2
Necklaced dove (<i>Spilopelia tigrina</i>)	4
Zebra dove (<i>Geopelia striata</i>)	4
Bar-shouldered dove (<i>Geopelia humeralis</i>)	2
Inca dove (<i>Scardafella inca</i>)	2
Cuban ground dove (<i>Chamaepelia passerina affarida</i>)	2
Green-winged dove (<i>Chalcophaps indica</i>)	3
New Guinea green dove (<i>Chalcophaps chrysocollora</i>)	6
Ringed turtle-dove (<i>Streptopelia risoria</i>)	2

PSITTACIFORMES.

Kea (<i>Nestor notabilis</i>)	4
Cockateel (<i>Calopsitta nomenclandiae</i>)	2
Roseate cockatoo (<i>Kakatoe roseicapilla</i>)	22
Bate-eyed cockatoo (<i>Kakatoe gymnopsis</i>)	3
Leadbeater's cockatoo (<i>Kakatoe leadbeateri</i>)	1
White cockatoo (<i>Kakatoe alba</i>)	2
Sulphur-crested cockatoo (<i>Kakatoe galerita</i>)	8
Great red-crested cockatoo (<i>Kakatoe moluccensis</i>)	1
Mexican green macaw (<i>Ara mexicana</i>)	2
Blue-and-yellow macaw (<i>Ara aurantia</i>)	2
Red-and-blue-and-yellow macaw (<i>Ara macao</i>)	8
Yellow-winged parrot (<i>Tyrionus virescens</i>)	1
Tui parrot (<i>Brotogeris sthomas</i>)	2
Tovi parrot (<i>Brotogeris jugularis</i>)	2
Yellow-naped parrot (<i>Amazona auropalliata</i>)	2
Yellow-cheeked parrot (<i>Amazona autumnalis</i>)	1
Orange-winged parrot (<i>Amazona amazonica</i>)	1
Red-crowned parrot (<i>Amazona viridigularis</i>)	6
Double yellow-head parrot (<i>Amazona oratrix</i>)	8
Yellow-headed parrot (<i>Amazona ochrocephala</i>)	2
Festive parrot (<i>Amazona festiva</i>)	1
Cuban parrot (<i>Amazona leucoccephala</i>)	1
Gray parrot (<i>Psittacus erithacus</i>)	2
Lesser vasa parrot (<i>Coracopsis nigra</i>)	1
Pennant's parrot (<i>Platycercus elegans</i>)	1
Rosella parrot (<i>Platycercus eximius</i>)	1
Black-tailed parrot (<i>Polytelus melanura</i>)	2
Red-rumped parrot (<i>Psephenops hammondi</i>)	1
Ring-necked parrot (<i>Cunurus torquatus</i>)	1
Nepalese parrot (<i>Cunurus nepalensis</i>)	1
Grass parrot (<i>Melopsittacus undulatus</i>)	6

CORACIFORMES.

Giant kingfisher (<i>Dacelo gigas</i>)	4
Short-billed toucan (<i>Ramphastos picivorus breviparvatus</i>)	1
Barred owl (<i>Nyctala varia</i>)	7
Snowy owl (<i>Nyctala nyctala</i>)	2
Screech owl (<i>Otus asio</i>)	3
Great horned owl (<i>Bubo virginianus</i>)	11

CORACIIFORMES—Continued.

Western horned owl (<i>Bubo virginianus pallescens</i>)	1
American barn owl (<i>Tyto perlata pratincola</i>)	3

PASSERIFORMES.

Silver-eared hill-tit (<i>Mesia argentea</i>)	3
Red-billed hill-tit (<i>Liothrix luteus</i>)	8
Black-gorgeted laughing-thrush (<i>Garrulax pectoralis</i>)	3
White-eared bulbul (<i>Otocompsa leucotis</i>)	3
European blackbird (<i>Turdus merula</i>)	2
Robin (<i>Planesticus migratorius</i>)	1
Cedar waxwing (<i>Bombycilla cedrorum</i>)	1
Piping crow-shrike (<i>Gymnorhina tibicen</i>)	4
Count Raggi's hrd of paradise (<i>Paradisaea raggiana</i>)	2
Satin bower-bird (<i>Ptilonorhynchus violaceus</i>)	2
European raven (<i>Corvus corax</i>)	1
Australian crow (<i>Corvus coronoides</i>)	1
Jackdaw (<i>Corvus monedula</i>)	1
Yucatan jay (<i>Cissilophya yucatanica</i>)	1
Blue jay (<i>Cyanocitta cristata</i>)	3
Green jay (<i>Xanthoura luteosa</i>)	1
Australian gray jumper (<i>Struthidea cinerea</i>)	1
Starling (<i>Sturnus vulgaris</i>)	9
Crimson tanager (<i>Ramphocelus dimidiatus</i>)	1
Blue tanager (<i>Thraupis cana</i>)	2
Shaft-tailed whydah (<i>Tetrænura regia</i>)	2
Napoleon weaver (<i>Pyromelana afra</i>)	1
Red-billed weaver (<i>Quelea quelea</i>)	1
Madagascar weaver (<i>Foudia madagascariensis</i>)	3
Fire finch (<i>Lagonosticta senegala</i>)	2
Strawberry finch (<i>Amandaya amandava</i>)	6
Cordon bleu (<i>Estrilda phainotis</i>)	1
Nutmeg finch (<i>Munia punctulata</i>)	7
White-headed nun (<i>Munia maja</i>)	4
Black-headed nun (<i>Munia atricapilla</i>)	2
Java finch (<i>Munia oryzivora</i>)	6

PASSERIFORMES—Continued.

White Java finch (<i>Munia oryzivora</i>)	3
Fawn-and-white bengalee (<i>Uroloncha flammaculata</i>)	4
Brown-and-white bengalee (<i>Uroloncha griseomaculata</i>)	3
Black-faced Gouldian finch (<i>Poephila gouldii</i>)	4
Diamond finch (<i>Steganopleura guttata</i>)	8
Zebra finch (<i>Taniopygia castanotis</i>)	4
Cutthroat finch (<i>Amadina fasciata</i>)	3
Vera Cruz red wing (<i>Agelaius phoeniceus richmondi</i>)	2
Golden-hooded oriole (<i>Icterus chryscephalus</i>)	1
Purple grackle (<i>Quiscalus quiscula</i>)	5
Yellow-backed cacique (<i>Cacicus cela</i>)	2
Black-tailed hawfinch (<i>Eophona melanura</i>)	1
Bullfinch (<i>Pyrrhula pyrrhula</i>)	5
Greenfinch (<i>Chloris chloris</i>)	3
Yellowhammer (<i>Emberiza citrinella</i>)	4
European goldfinch (<i>Carduelis carduelis</i>)	1
Bramblefinch (<i>Fringilla montifringilla</i>)	6
European siskin (<i>Spinus spinus</i>)	2
Mexican goldfinch (<i>Astragalinus psaltria mexicanus</i>)	1
House finch (<i>Carpodacus mexicanus frontalis</i>)	2
Purple finch (<i>Carpodacus purpureus</i>)	1
Canary (<i>Serinus canarius</i>)	15
Green singing finch (<i>Serinus icterus</i>)	1
Slate-colored junco (<i>Junco hyemalis</i>)	2
Tree sparrow (<i>Spizella monticola</i>)	1
White-throated sparrow (<i>Zonotrichia albicollis</i>)	4
Song sparrow (<i>Melospiza melodia</i>)	1
San Diego song sparrow (<i>Melospiza melodia cooperi</i>)	4
Fox sparrow (<i>Passercula iliaca</i>)	2
California towhee (<i>Pipilo crissalis</i>)	2
Saffron finch (<i>Sicalis flaveola</i>)	3
Seed eater (<i>Sporophila gutturalis</i>)	2
Nonpareil (<i>Passerina ciris</i>)	15
Blue grosbeak (<i>Guiraca caerulea</i>)	1
Red-crested cardinal (<i>Paroaria carolinensis</i>)	1
Cardinal (<i>Cardinalis cardinalis</i>)	2

REPTILES.

Alligator (<i>Alligator mississippiensis</i>)	36	Coach-whip snake (<i>Coluber flagellum</i>)	1
Teguexin (<i>Tupinambis teguixin</i>)	2	Chicken snake (<i>Elaphe quadrivittata</i>)	1
Gila monster (<i>Heloderma suspectum</i>)	7	Gopher-snake (<i>Dryomarekon concolor</i>)	1
Tree iguana (<i>Iguana iguana</i>)	5	Pine snake (<i>Pituophis melanoleucus</i>)	5
Rock iguana (<i>Cyclura carolinensis</i>)	4	King snake (<i>Lampropeltis getulus</i>)	2
Horned toad (<i>Phrynosoma cornutum</i>)	1	Milk snake (<i>Lampropeltis triangulum</i>)	1
Rock python (<i>Python molurus</i>)	2	Water snake (<i>Natrix sipedon</i>)	3
Anaconda (<i>Eunectes murinus</i>)	2	Queen snake (<i>Natrix septemvittata</i>)	1
Boa constrictor (<i>Constrictor constrictor</i>)	1	Garter snake (<i>Thamnophis sirtalis</i>)	3
Spreading adder (<i>Heterodon contortrix</i>)	1	Moccasin (<i>Agkistrodon piscivorus</i>)	1
Blacksnake (<i>Coluber constrictor</i>)	1	Western diamond rattler (<i>Crotalus atrox</i>)	2

Ground rattler (<i>Sistrurus miliarius</i>)	2	Central American cooter (<i>Pseudemys ornata</i>)	1
Snapping turtle (<i>Chelydra serpentina</i>)	2	Gopher tortoise (<i>Gopherus polyphemus</i>)	2
Rossignol's snapping turtle (<i>Chelydra rossignolii</i>)	1	Duncan Island tortoise (<i>Testudo ephippium</i>)	1
Wood turtle (<i>Clemmys insculpta</i>)	2	Indefatigable Island tortoise (<i>Testudo porteri</i>)	1
Diamond-back terrapin (<i>Malaclemys centrata</i>)	1	Albemarle Island tortoise (<i>Testudo vicina</i>)	2
Painted turtle (<i>Chrysemys picta</i>)	1		
Cooter (<i>Pseudemys scripta</i>)	1		

STATEMENT OF THE COLLECTION.

Accessions during the year.

	Mammals.	Birds.	Reptiles.	Totals.
Presented.....	52	73	53	178
Born and hatched in National Zoological Park.....	55	21		76
Received in exchange.....	57	152	6	215
Purchased.....	9	45	9	63
Transferred from other Government departments.....	62	2		64
Captured in National Zoological Park.....		5	2	7
Deposited.....		9	1	10
Total.....	235	307	71	613

SUMMARY.

Animals on hand July 1, 1920.....	1,427
Accessions during the year.....	613
Total animals handled.....	2,040
Deduct loss (by exchange, death, and return of animals on deposit).....	495
Animals on hand June 30, 1921.....	1,545

Class.	Species.	Individuals.
Mammals.....	198	541
Birds.....	246	901
Reptiles.....	34	103
Total, June 30, 1921.....	478	1,545

This is a gain in the collection of 59 species and 118 individuals over the total for June 30, 1920. The number of species shown is greater than ever before in the history of the park.

VISITORS.

For the second time the official attendance records exceed 2,000,000. The total number of visitors to the park for the fiscal year, as determined by count and estimate was 2,400,537, a gain of 171,232 over the record of last year. The greatest attendance in any one month was 390,988, in March, 1921, an average per day of 12,612.

The attendance by months was as follows: In 1920—July, 172,500; August, 211,600; September, 190,900; October, 323,150; November, 104,548; December, 78,050. In 1921—January, 171,776; February, 103,375; March, 390,988; April, 193,975; May, 276,475; June, 183,500.

One hundred and twenty-four schools and classes, with a total of 13,629 individuals, visited the park during the year. The number is greatly in excess of previous years, which have shown a steady increase. The American Ornithologists' Union, then in convention in Washington, visited the park on November 12, 1920; and the American Society of Mammalogists held an informal meeting, with luncheon, at the superintendent's office May 4, 1921.

IMPROVEMENTS.

About 150 chestnut trees, many of large size, that had been killed during the past few years by the prevalent bark disease, were logged during the winter. A small, secondhand sawmill and a shingle mill were purchased at low cost, and 140,000 feet of choice chestnut lumber and about 80,000 shingles were salvaged by the operations. The dead chestnut trees were scattered through the undeveloped forest area in the northwestern part of the park, bordering Klinge Road; and as great care was taken in logging, there has resulted very little damage to the beauty of the wood. A few young chestnut trees not yet affected by the blight were left standing. With the sawmill on hand it will be possible to save much choice lumber from time to time as trees die or are removed in the development of the park.

In continuation of the policy inaugurated two years ago, of widening the main automobile roads crossing the park, the section of roadway between the concourse and the scales near the camel yards and stable was broken up and rebuilt. Other sections of the roads were repaired, and the ford across Rock Creek near Klinge entrance was rebuilt with cement and the approaches improved. A cement sidewalk, 10 feet wide, corresponding to the walk on the north side of the entrance road at the Harvard Street gate was constructed on the south side from this entrance to the cement bridge. The number of visitors entering the park by this gate has greatly increased with the development of the Mount Pleasant section of the city, and the increased sidewalk area has been badly needed for several years.

The great flight cage for large birds has been entirely cleaned, the steel framework and wire covering scraped, and treated to two coats of paint. The roof of the camel and llama house has been repaired; and a new hot-water heating boiler installed in the monkey house.

Minor improvements made during the year include Telford pavements in several of the paddocks, a shed for tools at the machine shop, preparation of a large paddock for the mountain goats, new

guard rails bordering the inclosure for the Sumatran elephants, painting of the puma cages and other ironwork, and the construction of new trash receptacles and park benches.

CLEAN-PARK CAMPAIGN.

Regardless of park regulations, the paper and trash nuisance reached such serious proportions during the early spring months that a special campaign to enforce the laws against throwing and leaving rubbish on the lawns was inaugurated. With few exceptions visitors have taken kindly to the requests of officers that all papers and other refuse be gathered up and deposited in the trash receptacles, and a very distinct improvement in the appearance of the grounds has resulted.

With the greatly increased attendance, and especially with the present popularity of the grounds for picnic purposes, the absolute enforcement of the rubbish law is imperative. Additional trash baskets have been provided, and it is the intention to carry the campaign to a point where every visitor will realize the importance of the regulations and the seriousness of a disregard for park cleanliness. The aid of the public has been solicited by signs calling attention to the paper and trash nuisance, with a request for help. The response from the majority of visitors is gratifying, and the untidy small minority will, if necessary, be dealt with by sterner methods.

ALTERATIONS OF BOUNDARIES.

The purchase of the land necessary for the protection of the Connecticut Avenue entrance was completed during the year. The area acquired by purchase, and the included highways which by the same act become a part of the National Zoological Park, make an addition of 247,261.9 square feet or approximately $5\frac{3}{4}$ acres. The total area of the National Zoological Park is now about 175 acres. The unexpended balance of \$2,403.66, left from the appropriation of \$80,000 made for the purchase of this land, is reappropriated in the sundry civil bill for 1922 toward the purchase of certain lots near the Adams Mill Road entrance to the park, between the park and Adams Mill Road. The owners having declined to sell these lots within the price limits set by the act, steps have been taken toward the institution of proceedings of condemnation.

IMPORTANT NEEDS.

Restaurant.—The most urgent improvement needed for the park is a suitable public restaurant. As pointed out in previous reports, the old refreshment stand, originally constructed as a temporary building when the attendance was only a small fraction of its present

figures, is not only in a bad state of repair but is wholly inadequate for the required service. The estimated cost of a suitable building a year ago was \$65,400. Since the park has now obtained, as mentioned above, a large quantity of first-class chestnut lumber, including many heavy timbers, new plans have recently been drawn by the municipal architect with the idea of utilizing this lumber to advantage. It is now believed that a restaurant building in every way suitable to the demands of the place, and probably more in keeping with the surroundings, can be constructed for \$40,000.

Small-mammal house.—A building properly constructed for the exhibition of small mammals has long been needed, but never so much as at the present time. Numerous small animals now in the collection can not be shown for lack of quarters, and it is evident that more and more interest is being taken by visitors in the smaller species now on exhibition.

Grading banks and filling ravines.—During the present year some progress will be made in continuing the work of grading in the west-central part of the park. This work was begun five years ago but was discontinued during the war. Not only will a large area of comparatively flat space for deer yards and other paddocks result from the work, but the filling in of a near-by ravine will make possible the elimination of a dangerous curve in the main automobile road. It is greatly to be hoped that it will be possible to complete this work within the next year, so that the unsightly condition of that portion of the park adjoining the principal highway of traffic can be corrected and the ground utilized to advantage for the exhibition of animals.

Respectfully submitted.

N. HOLLISTER,
Superintendent.

DR. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 7.

REPORT ON THE ASTROPHYSICAL OBSERVATORY.

Sir: The Astrophysical Observatory was conducted under the following passage of the sundry civil act, approved June 5, 1919:

Astrophysical Observatory: For maintenance of the Astrophysical Observatory, under the direction of the Smithsonian Institution, including assistants, purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, repairs and alterations of buildings, and miscellaneous expenses, \$13,000.

The observatory occupies a number of frame structures within an inclosure of about 16,000 square feet south of the Smithsonian administration building at Washington, and also a cement observing station and frame cottage for observers on a plot of 10,000 square feet leased from the Carnegie Solar Observatory, on Mount Wilson, Calif.

A new solar observing station was erected in July, 1920, at the expense of funds donated for the purpose by Mr. John A. Roebling, of Bernardsville, N. J., and this station has been occupied as a solar radiation observing station by the Astrophysical Observatory since October, 1920.

The present value of the buildings and equipment for the Astrophysical Observatory owned by the Government is estimated at \$50,000. This estimate contemplates the cost required to replace the outfit for the purposes of the investigation.

WORK OF THE YEAR.

At Washington.—The preparation of the manuscript for Volume IV of the Annals of the Observatory was continued. Owing to the postponement of its publication, it has required to be brought up to date by repeated additions and modifications, and it is now expected to publish in Volume IV all the results up to September, 1920, when the solar radiation apparatus which had been employed on Mount Wilson was removed to Mount Harqua Hala, Ariz. A great deal of measuring and computing was required to bring up to date the work of 1919 and 1920 on the solar constant of radiation and to work up the results of the observations of the distribution of light over the sun's disk, which have been carried on since 1916 with only partial reduction. This work went on under Mr. Fowle's direction, assisted by Mrs. Bond, computer, and for a few months by temporary computers, Miss Inez Ensign and Miss Esther Weaver. The cost of em-

playing these computers temporarily was borne by a gift of Mr. John A. Roebeling. At the close of the fiscal year the computations of the Annals had been very nearly completed. The manuscript of the volume was also almost ready for publication, and it is hoped to put the whole to press early in the autumn of 1921.

As usual, a large amount of delicate instrument work has been done by Mr. A. Kramer, instrument maker, and still more delicate parts have been prepared by Mr. L. B. Aldrich, of the observatory staff. They have prepared and standardized a number of pyrheliometers, pyranometers, galvanometers, and bolometers for the use of the observatory and its stations.

By invitation of Dr. George E. Hale, director of the Solar Observatory at Mount Wilson, Calif., Doctor Abbot has undertaken the preparation of a special spectrobolometer for the observation of the energy spectra of the stars in the same manner in which we are accustomed to observe the energy spectrum of the sun. This outfit comprises a special spectroscope, a vacuum bolometer of special dimensions and construction, and a vacuum galvanometer designed to be of the very highest order of sensitiveness. The construction of this apparatus had been almost completed at the close of the fiscal year.

Work in the field.—As stated in last year's report, by the generosity of Mr. John A. Roebeling, of Bernardsville, N. J., not only has the private station of the Smithsonian Institution located near Calama, Chile, been removed to the top of a mountain about 8 miles farther south, but the station of the Astrophysical Observatory has been relocated on the mountain called Harqua Hala, situated about 100 miles to the northwest of Pheonix, Ariz. In June, 1920, Doctor Abbot selected the site for the latter station and arranged with local contractors for the erection of an adobe building about 40 feet long, 10 feet wide, of two stories. The lower story, underground, was designed for the instruments, and the upper story for a dwelling house and computing rooms for the observers. Proceeding from Arizona to Mount Wilson, Doctor Abbot was joined early in July by Mr. L. B. Aldrich, and together they carried out at Mount Wilson, in July, August, and part of September, the usual observations on the solar constant of radiation and on the distribution of radiation over the sun's disk. In addition, they conducted a number of other investigations, including a redetermination of the constants of the secondary pyrheliometers employed in the research, a redetermination of the transmission of the spectrobolometer for different wave lengths, various investigations with the pyranometer and the Ångström pyrgeometer, and, assisted by Mrs. Abbot, investigations on the use of solar radiation for cooking purposes.

The solar cooking outfit erected on Mount Wilson some years ago was in 1920, for the first time, brought to a reasonable degree of per-

fection. The mirror, which is of parabolic cylindrical shape, about 10 feet long and 7 feet wide, brings the solar radiation to focus on a tube filled with oil which passes up the axis of the mirror, parallel to the earth's axis, and about this tube, on suitable rollers, the mirror is rotated by means of a simple and inexpensive clockwork, in order that it may always face toward the sun. The oil tube is connected with a reservoir of oil about 10 feet higher up and from this a return tube goes underneath the mirror, thus completing the circuit for the flow of oil which the mirror, by focusing the sun rays, strongly heats. The reservoir contains about a barrel of oil, which is such as is used for lubricating gas-engine cylinders. The reservoir and the oil circuit tubes are protected from the loss of heat, as far as possible, by insulation. The greatest loss of heat, however, occurs with the naked tube which passes through the mirror. This, however, is protected by a glass tube 4 inches in diameter, and this, in turn, by flat sheets of glass covering the whole mirror and protecting it from dust and wind. Two ovens are inserted in the rear of the reservoir, which is just outside the door of the observer's cottage on Mount Wilson, and food after being prepared in the kitchen, may be baked, boiled, or stewed in these ovens, according to the character of the dish. Nearly all of the food prepared for the use of the observers during their stay on Mount Wilson, from July 1 to September 15, was cooked by this solar cooker. The great advantage of the cooking is that the reservoir stays hot for a good many hours, so that cooking may be continued through the night or even through a partially cloudy day. The apparatus proved to be especially satisfactory for the canning of fruit.

In the early part of September Messrs. Abbot and Aldrich packed the apparatus which had been used on Mount Wilson for observing the solar constant of radiation and shipped the same to Wenden, Ariz., the nearest railroad station leading to Mount Harqua Hala. The apparatus was set up for observations by the end of September, and Doctor Abbot, with Mr. F. A. Greeley as assistant, carried on solar radiation measurements beginning October 3 continuously until January 20, 1921, when Doctor Abbot was relieved by Mr. L. B. Aldrich, who in turn was relieved by Mr. A. F. Moore, formerly director of the observatory at Calama and Montezuma, Chile, who reported for duty about April 20. It is intended to carry on the solar constant observations at Mount Harqua Hala on all days when the weather permits for several years in cooperation with the similar observations being made at Montezuma, Chile. With the results of the two stations, it is hoped to furnish a sound basis for the study of solar variation and the dependence of terrestrial weather conditions thereon. The station at Mount Harqua Hala was erected after a

considerable investigation by the United States Weather Bureau of sites in California, Arizona, and Nevada. From the middle of September, when Messrs. Abbot and Aldrich arrived in the vicinity, until some time in February the conditions were found to be superior to what had been expected. About 70 per cent of the days during that interval were fit for observation. The months of March, April, and May proved to be less satisfactory than was anticipated, owing to a thick haziness and much cirrus cloud. This defect, however, seems to be attending the generally unusual character of the weather in large areas of the globe. During the first four months of the year 1921, for instance, hardly more than half of the usual number of observations were made at the station in Chile, and other facts might be cited which would tend to show that the earlier part of the year 1921 was of very unusual character from a weather standpoint.

The station on Mount Harqua Hala, being 15 miles from Wenden, the railroad station, and 5 miles from a wagon road, is very isolated. The effect of such isolation on the morale of observers was very thoughtfully considered by Mr. John A. Roebeling, and he added considerably to his first gift in order to provide a great many things for the comfort and recreation of the observers, both in Arizona and South America. Not all of these arrangements had been completed at the close of the fiscal year, so that mention of them may be deferred more properly to next year's report.

PERSONNEL.

Miss F. A. Graves resigned as computer on August 10, 1920.

SUMMARY.

The year has been marked by the transfer of the solar radiation measurements from Mount Wilson, Calif., to Mount Harqua Hala, Ariz., to secure more perfect weather conditions. It is intended to continue solar constant observations there daily when possible throughout the entire year for several years. Similar duplicate observations are to be carried on at Montezuma, Chile, at the private station of the Smithsonian. Thus it is hoped to provide an excellent basis of solar radiation measurements to compare with weather phenomena. This may lead to advance in methods of weather forecasting. Volume IV of the annals, covering the years 1912 to 1920, is practically ready for the press.

Respectfully submitted.

C. G. ABBOT,
Director.

DR. C. D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 8.

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

SIR: I have the honor to submit the following report on the operations of the United States Bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1921:

All volumes of the fourteenth annual issue have been published, completing the catalogue through the year 1914. Financial conditions, brought about by the war and the excessive advance in the cost of publication, have since made it necessary to temporarily suspend printing the catalogue. Much of the material for 1915 and subsequent years is in the hands of the London central bureau ready for publication as soon as financial support is assured and publication costs are more nearly normal.

The work of this bureau during the year has consisted in collecting data from periodicals regularly publishing scientific papers, of which there are about 550 in the United States. In addition to these there are over 400 occasionally containing scientific matter. Book notices, reviews, and publishers' lists and the publications received through exchange by the Smithsonian Institution are also systematically used in order to make sure that no paper coming within the scope of the catalogue is overlooked. Reference slips are prepared for each paper thus collected, and the contents classified to conform to the International Catalogue subject schedule. Practically all of the classification is done by specialists, and much difficulty is experienced in obtaining suitable aid for this part of the work, owing to the very limited funds available. This lack of funds has always seriously interfered with the work of the bureau; but as much of the data through the year 1920 have been classified and are now held pending the resumption of publication, it is hoped that by the time it is called for by the central bureau most of the index cards will be ready, and that when the published volumes have been brought up to date a larger annual appropriation will be granted, so that all current publications may be immediately dealt with.

When it is considered that between 25,000 and 30,000 reference cards have annually been furnished by this bureau, some idea of the amount of expert and clerical labor involved is apparent.

As a résumé of the history of the enterprise was published in the report of this bureau for the last fiscal year, it is unnecessary to again repeat it excepting to state that financial difficulties have not been relieved, although, owing to assurances made by influential delegates

to a conference held under the auspices of the Royal Society in London during September, 1920, it appears that if certain conditions can be met financial support may be looked for from the United States. This conference, called by the Royal Society to consider the future of the International Catalogue of Scientific Literature, was held in London September 28 and 29, 1920. The following delegates attended, representing the countries named: Denmark, Prof. M. Knudsen; France, M. A. Lacroix; Holland, Dr. G. van Rijnberk; Japan, Dr. Hantaro Nagaoka; Norway, Mr. Rolf Laache; Sweden, Baron Alströmer; Switzerland, Dr. Hermann Escher. Dr. Marcel Godet, Dr. H. Field; United States, Dr. Robert M. Yerkes (National Research Council), Dr. L. E. Dickson (National Academy of Sciences), Mr. L. C. Gunnell (Smithsonian Institution); India, Sir H. H. Hayden, F. R. S.; New Zealand, Prof. A. Denby, F. R. S.; Victoria, Prof. E. W. Skeats; South Africa, Sir Thomas Muir, F. R. S.; West Australia, Mr. C. B. Rushton. Representing the Royal Society: Sir Joseph Thompson, president R. S.; Sir David Prain, treasurer R. S.; Mr. J. H. Jeans, secretary R. S.; Prof. H. E. Armstrong, F. R. S.; Dr. F. A. Bather, F. R. S.; Dr. P. C. Mitchell, F. R. S.; Sir Arthur Schuster, F. R. S. There were also present Dr. S. I. Franz (United States of America), representing the Rockefeller Foundation, and Sir F. G. Ogilvie and Mr. L. S. Lloyd (Great Britain). Two Italian delegates, Prof. Raffaello Nasini and Comm. Ing. Ernesto Mancini, were delayed on the journey and did not arrive until the end of the conference. These two distinguished Italian representatives were very earnest in their desire to see the catalogue continued, and both agreed with the decisions of the other delegates.

After two days taken up in considering the financial situation as presented by the Royal Society, and discussion of the general affairs of the enterprise, the following resolutions were agreed on unanimously:

1. That the catalogue should be temporarily continued in its present form for the year 1915 and possibly also as a single issue for the period 1916-1920, provided adequate financial support can be obtained.

That at the earliest possible date opportunity be taken to reconsider the whole character of the subsequent work of organization.

That one of the first questions to be considered be the possibility of converting the International Catalogue of Scientific Literature into a cumulative subject and authors' index, the volumes of which shall be published at intervals of 3, 5, or 10 years, in accordance with the status and needs of their respective sciences; and that the materials shall be obtained so far as practicable in co-operation with the abstracting journals of the world and other agencies affording rapid information, including regional bureaus.

It was also agreed unanimously—

2. That, inasmuch as the Royal Society is no longer able to accept financial responsibility for the catalogue, it is essential that adequate financial support, including working capital, be provided.

Further, the opinion was expressed by the delegates generally (other than those representing the Royal Society) that the Royal Society, being relieved of financial responsibility, should otherwise act as heretofore.

Finally the conference resolved—

3. That a committee be appointed to draw up definite proposals in accordance with the above resolutions and that the report of the committee be forwarded to the council of the Royal Society.

4. That the council of the Royal Society be requested to take such steps with regard to the recommendations of this committee as they think fit.

The committee appointed under the resolution 3 made the following recommendations, subject to adequate financial provision being assured:

(a) That the central bureau be instructed to proceed with publication of the 1915 issue.

(b) That the central bureau be further instructed to collect material for the period 1916=1920 with a view to the early publication of the issue 1916=1920.

The committee further recommended—

(c) That the council of the Royal Society request the executive committee of the International Council of the Catalogue to proceed to collect information as to the various issues raised in the foregoing resolutions of the conference and to report at as early a date as possible.

The fourteenth issue was not completed at the time of the meeting. Below is a table showing the receipts and expenditures of the London central bureau on account of the first 13 issues:

	Receipts.			Expenditures.		
	£	s	d	£	s	d
First issue.....	7,083	10	3	7,117	0	0
Second issue.....	7,168	16	4	7,115	2	7
Third issue.....	7,152	15	10	6,807	5	1
Fourth issue.....	7,010	14	1	7,009	19	5
Fifth issue.....	6,745	13	10	8,216	17	8
Sixth issue.....	6,717	14	7	7,895	10	1
Seventh issue.....	7,372	17	1	7,493	1	10
Eighth issue.....	7,079	4	6	7,281	1	5
Ninth issue.....	7,212	17	7	6,917	3	8
Tenth issue.....	7,183	11	5	7,271	12	7
Eleventh issue ¹	6,796	18	4	6,894	16	8
Twelfth issue.....	5,580	17	10	6,752	11	6
Thirteenth issue ²	5,611	9	10	8,783	11	6
	58,747	4	6	93,555	14	0

¹ The war began before the eleventh issue was completed, so that the falling off in receipts during the last three years may be attributed to loss of subscriptions from Germany, Austria, Hungary, Poland, and Belgium.

² The increased expenditures on the thirteenth issue arise from that issue having taken two years instead of one to complete.

From this table it will be seen that on the completion of the tenth issue, before war conditions interfered, receipts and expenditures practically balanced, and it is apparent that had not these unex-

pected conditions arisen the whole enterprise would have been self-sustaining. Before war began many changes were contemplated to improve the service rendered by the catalogue and bring it more nearly to the high standard set by the original brilliantly conceived plan which so many of the world's leading men of science had taken part in formulating and which was referred to in some detail in the last annual report of this bureau.

There is and has been no question of the need and value of an International Catalogue of Scientific Literature, and it is the opinion of almost everyone interested in such matters that no better plan has ever been presented to accomplish the ends sought. Any new enterprise would lack the greatest present asset of the catalogue, which is the official support of most of the civilized nations, and it is with this support practically assured for the future that the catalogue will start in its endeavor to gain the financial assistance necessary to compensate for losses caused by the late war.

New agencies, such as abstract journals representing all branches of science, are to be undertaken by other organizations, and it is through cooperation with these that the catalogue is to be produced in the future, thus meeting all requirements of scientific workers as well as those of reference libraries and of those engaged in general investigation.

From the attitude of the foreign delegates at the conference it is apparent that there exists no lack of interest or desire to continue the work, but all of these countries are now under unprecedented financial strain, which is greatly increased by abnormal rates of exchange, so for the present, at least, their aid must be less than it would be during normal times. There is in this country a growing interest in supplying the needs of scientific workers, and plans are under way to publish abstract journals in all branches of science not already represented. These plans were brought to the notice of the conference by the American delegates, representing the National Academy of Sciences, the National Research Council, and by a representative of the Rockefeller Foundation, who was present. From statements there made it appears that the money needed to establish these enterprises is available and the resolutions of the conference took into account cooperation with these new organizations for the common benefit of the publishing bodies and of scientific investigators.

Very respectfully, yours,

LEONARD C. GUNNELL,
Assistant in Charge.

DR. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 9.

REPORT ON THE LIBRARY.

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution for the fiscal year ended June 30, 1921:

The number of packages received was 27,327, an increase over the preceding year of 3,577. Of these 25,156 were received by mail and 2,171 through the International Exchange Service. Many of the packages received through the international exchanges, it might be mentioned, were exceptionally large, consisting of publications issued during the years 1914 to 1920, when it was not possible to send them on account of the war.

SMITHSONIAN MAIN LIBRARY.

In order that material received for the Smithsonian Library may be made available to the public at the earliest possible moment, publications have been transmitted daily, as in years past, to the Smithsonian deposit in the Library of Congress. The number of publications so transmitted was 6,250, composed of 4,910 complete volumes, 607 parts of volumes, 721 pamphlets, and 12 charts. The accession numbers extended from 534,619 to 537,229. Four thousand four hundred and sixty-four foreign government documents, presented to the Smithsonian Institution were transferred to the Library of Congress in accordance with the established practice.

Material from abroad has been steadily coming in, and the receipts for the year have been much larger than was anticipated. The number of authors' reprints and theses from German universities and institutes of technology has been exceptionally large, covering the years 1914 to 1920. These were received from the universities of Berlin, Breslau, Frankfurt-am-Main, Freiburg-im-Breisgau, Halle-an-der-Saale, Heidelberg, Kiel, Leipzig, Marburg, Zürich, Dorpat, Helsingfors, Lund, Paris, Amsterdam, Brussels, Delft, Ghent, Leiden, and Utrecht; and from the institutes of technology at Berlin, Braunschweig, Stockholm, Utrecht, and Zürich.

Cataloguing.—As will be seen by comparison, the cataloguing accomplished has been more than double that of last year.

	1921	1920
Volumes catalogued.....	6,232	2,332
Volumes recatalogued.....	75	848
Library of Congress cards filed.....	757	618
Catalogue cards typed.....	4,926	2,280
New titles added to author catalogu.....	2,517	869

Large as the amount of cataloguing has been, however, in comparison with last year, it has not been sufficient to meet the demands occasioned by the receipts; and many of the reprints and theses remain uncatalogued.

Periodicals.—The number of entries at the periodical desk was 14,008. Nine hundred and forty-five volumes were completed.

Exchanges.—The securing of publications in exchange for the completion of sets in the Library of Congress has been continued, with the following results:

Number of want cards received from—		
Smithsonian division.....		291
Periodical division.....		90
Order division.....		48
Total.....		429
Number of publications secured for—		
Smithsonian division.....	Vols.	Parts.
Periodical division.....	290	255
Order division.....	19	201
	5	3
Total.....	324	459

OFFICE LIBRARY.

Accessions to the office library, including the aeronautical collection, the collection of Bonaparteana, the art room collection, and the employees' library, numbered 317 volumes, 4 parts of volumes, and 468 pamphlets. This does not include many periodicals, of which the current numbers are kept on file in the reading room, and the completed volumes transmitted at the end of the year to the Library of Congress. The library is greatly indebted to Dr. Frank Wigglesworth Clarke for the presentation of his unique collection of authors' reprints on the determination of the atomic weights, numbering 482 titles.

Circulation.—The total circulation of the Library was 3,485, consisting of 2,708 magazines borrowed from the reading room, 506 books from the employees' library, and 171 from the reference room. Many volumes which are not permitted to leave the building were

consulted, especially reference works and the books of the aeronautical collection and the De Peyster collection.

Bibliography.—The second volume of the Bibliography of Aeronautics, prepared by the assistant librarian, covering the period from 1909 to 1916, was completed and published by the National Advisory Committee for Aeronautics. This volume contains approximately 35,000 citations and cross references, and supplements the material contained in the volume published by the Smithsonian Institution as volume 55 of the Smithsonian Miscellaneous Collections. The aeronautical library is growing and becoming more and more important.

MUSEUM LIBRARY.

Continued interest has been manifested during the year in the increase of the scientific collections of the United States National Museum. Among those who have donated valuable material to the library may be mentioned Dr. J. M. Aldrich, Mr. H. S. Barber, Mr. A. H. Clark, Dr. William H. Dall, Dr. O. P. Hay, Dr. W. H. Holmes, Dr. Walter Hough, Dr. Aleš Hrdlička, Mr. W. R. Maxon, Dr. G. S. Miller, Dr. C. W. Richmond, Mr. J. H. Riley, Mr. S. A. Rohwer, Mr. W. Schaus, Mr. W. L. Schmitt, Dr. R. W. Schufeldt, Dr. L. Stejneger, Mr. B. H. Swales, Dr. Charles D. Walcott, and the late Dr. Joseph Paxson Iddings.

Especially worthy of mention is the library of the late Doctor Iddings, comprising upward of 1,000 books and pamphlets, chiefly on geological subjects. Doctor Iddings, as is well known, was one of America's leading petrologists, and his 40 years' accumulation of authors' excerpts on this branch of science was unusually large. The donation, made through his sister, Mrs. Francis D. Cleveland, is therefore important. Indeed it forms the most important single acquisition to the geological section of the library since the foundation of the department in 1880.

The geological and paleontological collections have been further augmented during the year by the continued gifts of the Secretary of the Smithsonian Institution, Dr. Charles D. Walcott, most of the books donated being volumes of highly technical content and of great value to those undertaking advanced researches along these lines.

The additions to the sectional library of the division of mollusks through the gift of Dr. William H. Dall have made possible a continued study in the United States National Museum of the more recently discovered mollusks and tertiary fossils. The library is greatly indebted to Doctor Dall, during these times when scientific books of this character are so expensive and so difficult to secure, for the continued interest year by year in the selection and presentation of so

many volumes for this section. The number of titles added this year by Doctor Dall was 317.

Accessions.—Four thousand seven hundred and sixty volumes were accessioned during the year, including 2,041 completed volumes and 2,719 pamphlets. The number of books in the library is now 150,067, of which 58,658 are bound volumes and 91,409 pamphlets and unbound papers.

Cataloguing.—Seven hundred and seventy-seven volumes and 2,643 pamphlets were catalogued.

Periodicals.—The number of periodicals entered was 15,427.

Loans.—The number of books loaned was 7,432. Of these, 1,778 were borrowed from the Library of Congress, and 105 from other libraries.

Binding.—Owing to the increased cost of binding, it has been possible to have only 692 books bound, most of these being volumes which could not be bound last year, when the funds for this purpose were exhausted in January, the allotment being sufficient for a period of six months only. This year the funds were exhausted in November, some two months earlier. An increased allotment for binding is earnestly recommended.

Technological series.—The compiling of a subject and title catalogue for material in the technological series is slowly progressing, and it is hoped that it may be brought to completion within the course of a year. Additions to the series, exclusive of duplicates, number 216 bound volumes, 133 pamphlets, 6,372 periodicals. To the scientific depository catalogue, 1,180 cards have been added, including author, title, and subject entries. The books and periodicals loaned number 210.

Sectional libraries.—Following is a list of sectional libraries:

Administration.	Mechanical technology.
Administrative assistant's office.	Minerals.
American archeology.	Mineral technology.
Anthropology.	Mollusks.
Birds.	Old World archeology.
Botany.	Paleobotany.
Editor's office.	Photography.
Ethnology.	Physical anthropology.
Fishes.	Property clerk.
Food.	Registrar's office.
Geology.	Reptiles and batrachians.
Graphic arts.	Superintendent's office.
History.	Taxidermy.
Insects.	Textiles.
Invertebrate paleontology.	Vertebrate paleontology.
Mammals.	War library.
Marine invertebrates.	Wood technology.
Medicine.	

ASTROPHYSICAL OBSERVATORY LIBRARY.

Additions to the library of the Astrophysical Observatory numbered 72 volumes, 12 parts of volumes, and 37 pamphlets.

BUREAU OF AMERICAN ETHNOLOGY LIBRARY.

The report of operations of the library of the Bureau of American Ethnology will be found in the report of that bureau. The library is administered under the direct care of the chief of that bureau.

NATIONAL GALLERY OF ART LIBRARY.

The library of the National Gallery of Art was during the past fiscal year administered under the direction of the library of the United States National Museum, and its accessions are included in the statistics given for that library.

FREER GALLERY OF ART LIBRARY.

Accessions to the library of the Freer Gallery of Art, including publications presented to the Smithsonian Institution and deposited there for reference use in connection with the Freer collections, number 113. Especially worthy of mention is the gift by Messrs. Ton-Ying & Co., of New York, in commemoration of Mr. Charles L. Freer, of 33 rare Chinese manuscripts of the Ming period, constituting 108 volumes.

NATIONAL ZOOLOGICAL PARK LIBRARY.

Eleven volumes were added to the library of the National Zoological Park during the year.

SUMMARY OF ACCESSIONS.

The accessions during the year, with the exception of those for the library of the Bureau of American Ethnology, may be summarized as follows:

To the Smithsonian deposit in the Library of Congress, including parts to complete sets-----	6,250
To the Smithsonian office, Astrophysical Observatory, Freer Gallery of Art, and National Zoological Park libraries-----	938
To the United States National Museum library, including accessions for the National Gallery of Art-----	4,760
Total-----	11,948

Respectfully submitted.

PAUL BROCKETT,
Assistant Librarian.

DR. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

APPENDIX 10.

REPORT ON THE PUBLICATIONS.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1921:

The Institution proper published during the year 7 papers in the series of Miscellaneous Collections, 1 annual report and pamphlet copies of 27 articles in the appendix to the report, a reprint of the Smithsonian Mathematical Tables, and two special publications. The Bureau of American Ethnology published three bulletins and a list of the publications of the bureau. The United States National Museum issued 1 annual report, 8 bulletins, 4 separate parts of bulletins, 51 separate papers from the proceedings, and 5 parts of volumes in the series Contributions from the United States National Herbarium.

The total number of publications distributed by the Smithsonian and its branches was 142,208, which includes 255 volumes and separates of the Smithsonian Contributions to Knowledge, 12,922 volumes and separates of the Smithsonian Miscellaneous Collections, 24,423 volumes and separates of the Smithsonian annual reports, 89,000 volumes and separates of the National Museum publications, 12,795 publications of the Bureau of American Ethnology, 2,000 special publications, 14 volumes of the Annals of the Astrophysical Observatory, 40 reports on the Harriman Alaska expedition, 414 reports of the American Historical Association, and 315 publications presented to but not issued by the Smithsonian Institution.

SMITHSONIAN MISCELLANEOUS COLLECTIONS.

Of the Smithsonian Miscellaneous Collections, volume 71, 1 paper was issued; volume 72, 6 papers; in all, 7 papers, as follows:

VOLUME 71.

No. 1. Smithsonian Physical Tables, Seventh Revised Edition. Prepared by Frederick E. Fowle. September 21, 1920. xvi+450 pp. (Publ. 2539.)

VOLUME 72.

No. 3. Reports upon two collections of mosses from British East Africa. By H. N. Dixon. September 1, 1920. 20 pp., 2 pls. (Publ. 2553.)

No. 4. Diagnoses of some new genera of birds. By Robert Ridgway. December 6, 1920. 4 pp. (Publ. 2558.)

- No. 5. New selaginellas from the western United States. By William R. Maxon. December 22, 1920. 10 pp., 6 pls. (Publ. 2589.)
- No. 6. Explorations and field-work of the Smithsonian Institution in 1920. May 12, 1921. 126 pp., 138 figs. (Publ. 2619.)
- No. 7. Sea-lilies and feather stars. By Austin H. Clark. April 28, 1921. 43 pp., 16 pls. (Publ. 2620.)
- No. 9. *Neobabbottia*, a new cactus genus from Hispaniola. By N. L. Britton and J. N. Rose. June 15, 1921. 6 pp., 4 pls. (Publ. 2651.)

SMITHSONIAN ANNUAL REPORTS.

REPORT FOR 1918.

The complete volume of the Annual Report of the Board of Regents for 1918, together with pamphlet copies of the papers in the general appendix, was received from the Public Printer during the year.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1918. xii + 612 pp., 54 pls., 128 text figs. (Publ. 2549.)

The appendix contained the following papers:

- The Discovery of Helium, and What Came of It, by C. G. Abbot. 5 pp. (Publ. 2550.)
- An Account of the Rise of Navigation, by R. H. Curtiss. 11 pp. (Publ. 2551.)
- The Tornadoes of the United States, by Prof. Robert DeC. Ward. 6 pp., 1 pl. (Publ. 2552.)
- Wind Power, by James Carlill. 9 pp. (Publ. 2553.)
- A Tribute. Samuel Pierpont Langley: Pioneer in Practical Aviation, by Henry Leffman. 10 pp., 9 pls. (Publ. 2554.)
- Twentieth Century Physics, by, R. A. Millikan. 19 pp. (Publ. 2555.)
- The Experiments of Dr. P. W. Bridgman on the Properties of Matter When Under High Pressure. Introductory Note by C. G. Abbot. 19 pp., 1 pl. (Publ. 2556.)
- The Problem of Radioactive Lead, by Theodore W. Richards. 14 pp. (Publ. 2557.)
- Sphagnum Moss: War Substitute for Cotton in Absorbent Surgical Dressings, by Prof. George E. Nichols. 13 pp., 4 pls. (Publ. 2558.)
- History of Military Medicine and its Contributions to Science, by Col. W. P. Chamberlain. 14 pp. (Publ. 2559.)
- Some Problems of International Readjustment of Mineral Supplies as Indicated In Recent Foreign Literature, by Eleanor F. Bliss. 18 pp. (Publ. 2560.)
- Reptile Reconstructions in the United States National Museum, by Charles W. Gilmore. 10 pp., 6 pls. (Publ. 2561.)
- A Pleistocene Cave Deposit in Western Maryland, by J. W. Gidley. 6 pp., 6 pls. (Publ. 2562.)
- Paleobotany: A Sketch of the Origin and Evolution of Floras, by Edward W. Berry. 118 pp., 6 pls. (Publ. 2563.)
- The Direct Action of Environment and Evolution, by Prince Kropotkin. 18 pp. (Publ. 2564.)
- The Law of Irreversible Evolution, by Branislav Petronievics. 11 pp. (Publ. 2565.)
- The Fundamental Factor of Insect Evolution, by S. S. Chetverikov. 8 pp., 1 pl. (Publ. 2566.)

- The Psychic Life of Insects, by E. L. Bouvier. 8 pp. (Publ. 2567.)
 Sexual Selection and Bird Song, by Chauncey J. Hawkins. 12 pp. (Publ. 2568.)
 Marine Camoufleurs and Their Camouflage: The Present and Prospective Significance of Facts Regarding the Coloration of Tropical Fishes, by W. H. Longley. 10 pp., 5 pls. (Publ. 2569.)
 Foot-Plow Agriculture in Peru, by O. F. Cook. 4 pp., 4 pls. (Publ. 2570.)
 Sun Worship of the Hopi Indians, by J. Walter Fewkes. 33 pp., 11 pls. (Publ. 2571.)
 A Constitutional League of Peace in the Stone Age of America: The League of the Iroquois and Its Constitution, by J. N. B. Hewitt. 18 pp. (Publ. 2572.)
 The Problem of Degeneracy, by H. F. Tredgold. 15 pp. (Publ. 2573.)
 History in Tools, by W. M. Flinders Petrie. 10 pp. (Publ. 2574.)
 The Background of Totemism, by E. Washburn Hopkins. 11 pp. (Publ. 2575.)
 A Great Naturalist: Sir Joseph Hooker, by Sir E. Ray Lankester. 16 pp. (Publ. 2576.)

REPORT FOR 1919.

The general appendix to the report for 1919, which was still in press at the close of the year, contains the following papers:

- Modern theories of the spiral nebulae, by Heber D. Curtis.
 A determination of the deflection of light by the sun's gravitational field, from observations made at the total eclipse of May 29, 1919, by Sir F. W. Dyson, A. S. Eddington, and C. Davidson.
 Wireless telephony, by N. H. Slaughter.
 Radium and the electron, by Sir Ernest Rutherford.
 The "HD-4." A 70-miler with remarkable possibilities developed at Dr. Graham Bell's laboratories on the Bras d'Or Lakes, by William Washburn Nutting.
 Natural resources in their relation to military supplies, by Arthur D. Little.
 Glass and some of its problems, by Sir Herbert Jackson.
 The functions and ideals of a national geological survey, by F. L. Ransome.
 The influence of cold in stimulating the growth of plants, by Frederick V. Coville.
 Floral aspects of British Guiana, by A. S. Hitchcock.
 Milpa agriculture, a primitive tropical system, by O. F. Cook.
 On the extinction of the mammoth, by H. Neuville.
 A preliminary study of the relation between geographical distribution and migration, with special reference to the Palaearctic region, by R. Meinertzhagen.
 The necessity of State action for the protection of wild birds, by Walter E. Collinge.
 Glimpses of desert bird life in the Great Basin, by Harry C. Oberholser.
 The Division of Insects in the United States National Museum, by J. M. Aldrich.
 The seventeen-year locust, by R. E. Snodgrass.
 Entomology and the war, by L. O. Howard.
 Two types of southwestern cliff houses, by J. Walter Fewkes.
 On the race history and facial characteristics of the aboriginal Americans, by W. H. Holmes.
 The opportunity for American archeological research in Palestine, by James A. Montgomery.
 The differentiation of mankind into racial types, by Arthur Keith.
 The exploration of Manchuria, by Arthur de C. Sowerby.

The origin and beginnings of the Czechoslovak people, by Jindřich Matiegka.
 Geographic education in America, by Albert Perry Brigham.
 Progress in national land reclamation in the United States, by C. A. Bissell.
 Richard Rathbun, by Marcus Benjamin.
 A great chemist: Sir William Ramsay, by Ch. Moureu.

REPORT FOR 1920.

The report of the executive committee and proceedings of the Board of Regents of the Institution and report of the secretary, both forming part of the annual report of the Board of Regents to Congress, were issued in pamphlet form in November, 1920.

Report of the executive committee and proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1920. 19 pp. (Publ. 2587.)

Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1920. 110 pp., 1 pl. (Publ. 2586.)

The general appendix to this report, which was in press at the close of the year, contains the following papers:

Studying the sun's heat on mountain peaks in desert lands, by C. G. Abbot.
 The habitability of Venus, Mars, and other worlds, by C. G. Abbot.

Giant suns, by H. H. Turner.

A bundle of meteorological paradoxes, by W. J. Humphreys.

The determination of the structure of crystals, by Ralph W. G. Wyckoff.

Dr. Aston's experiments on the mass spectra of the chemical elements, with introduction by C. G. Abbot.

Vitamins, by W. D. Halliburton.

Soil acidity—its nature, measurement, and relation to plant distribution, by Edgar T. Wherry.

The chemistry of the earth's crust, by Henry S. Washington.

Major causes of land and sea oscillations, by E. O. Ulrich.

The Bryozoa, or moss animals, by R. S. Bassler.

The horned dinosaurs, by Charles W. Gilmore.

Rhythm in nature, by F. W. Flattely.

Parasitism and symbiosis in their relation to the problem of evolution, by Maurice Canberry.

Local suppression of agricultural pests by birds, by W. L. McAtee.

The occult senses in birds, by Herbert H. Beck.

Adventures in the life of a fiddler crab, by O. W. Hyman.

The senses of insects, by N. E. McIndoo.

The resplendent shield-bearer and the ribbed-cocoon-maker: Two insect inhabitants of the orchard, by R. E. Snodgrass.

The origin of insect societies, by Auguste Lameere.

The botanical gardens of Jamaica, by William R. Maxon.

Narcotic daturas of the Old and New World; an account of their remarkable properties and their uses as intoxicants and in divination, by William R. Safford.

Effect of the relative length of day and night on flowering and fruiting of plants, by W. W. Garner and H. A. Allard.

Fire worship of the Hopi Indians, by J. Walter Fewkes.

Racial groups and figures in the Natural History Building of the United States National Museum, by Walter Hough.

- Notes on the dances, music, and songs of the ancient and modern Mexicans, by Auguste Genin.
- The Ralph Cross Johnson collection in the National Gallery at Washington, D. C., by George B. Rose.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM.

The publications of the National Museum are: (*a*) The annual report; (*b*) the Proceedings of the United States National Museum; and (*c*) the Bulletin of the United States National Museum, which includes the Contributions from the United States National Herbarium. The editorship of these publications is vested in Dr. Marcus Benjamin.

During the year ending June 30, 1921, the Museum published 1 annual report, 8 complete bulletins, 4 parts of bulletins, 5 parts of volumes in the series Contributions from the United States National Herbarium, and 51 separates from the proceedings.

The issues of the bulletin were as follows:

- Bulletin No. 106 (plates). North American early tertiary Bryozoa. By Ferdinand Canu and Ray S. Bassler.
- Bulletin No. 109. Contributions to a history of American State geological and natural history surveys. By George P. Merrill.
- Bulletin No. 110. Osteology of the carnivorous dinosauria in the United States National Museum, with special reference to the genera *Antrodemus* (*Allosaurus*) and *Ceratosaurus*. By Charles Whitney Gilmore.
- Bulletin No. 111. A monograph of the east American scaphopod mollusks. By John B. Henderson.
- Bulletin No. 112. Summary of the marine shell-bearing mollusks of the northwest coast of America, from San Diego, Calif., to the Polar Sea, mostly contained in the collection of the United States National Museum, with illustrations of hitherto unfigured species. By William Healey Dall.
- Bulletin No. 115. The fossil crinoid genus *Dolatocrinus* and its allies. By Frank Springer.
- Bulletin No. 116. The dipterous genus *Dolichopus latreille* in North America. By M. C. Van Duzee, F. R. Cole, and J. M. Aldrich.
- Bulletin No. 117. The distribution of bird life in the Urubamba Valley of Peru. A report on the birds collected by the Yale University—National Geographic Society's expeditions. By Frank M. Chapman.

Of the separate papers of bulletins, the following were issued:

- Bulletin 100. Contributions to the biology of the Philippine Archipelago and adjacent regions. Volume 1, part 7: The macrourid fishes of the Philippine Islands and the East Indies. By Charles Henry Gilbert and Carl L. Hubbs.
- Bulletin 100. Contributions to the biology of the Philippine Archipelago and adjacent regions. Volume 1, part 8: Polychaetous annelids collected by the United States Fisheries steamer *Albatross* in the waters adjacent to the Philippine Islands in 1907–1910. By A. L. Treadwell.
- Bulletin 100. Contributions to the biology of the Philippine Archipelago and adjacent regions. Volume 1, part 9: Polychaetous annelids collected by the United States Fisheries steamer *Albatross* during the Philippine Expedition of 1907–1909. By Ruth A. Hoagland.

Bulletin 104. The Foraminifera of the Atlantic Ocean. Part 2. Lituolidae.
By Joseph Augustine Cushman.

Of the separates from the proceedings, 5 were from volume 57, 29 from volume 58, and 17 from volume 59.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

The publications of the bureau are described in detail in Appendix 4 of this report. The editorial work of the bureau is under the direction of Mr. Stanley Scarles, editor.

During the past year three bulletins and a list of the publications of the bureau were published, as follows:

Bulletin 67. Alsea texts and myths. By Leo Frachtenberg. 304 pp.

Bulletin 71. Native cemeteries and forms of burial east of the Mississippi. By David I. Bushnell, jr. 160 pp., 17 pls.

Bulletin 72. The owl sacred pack of the Fox Indians. By Truman Michelson. 83 pp., 4 pls.

List of the publications of the Bureau of American Ethnology.

There were in press at the close of the year five annual reports and seven bulletins. The bulletins were as follows:

Bulletin 73. Early history of the Creek Indians and their neighbors. By John R. Swanton.

Bulletin 74. Excavation of a site at Santiago Ahuizotla, D. F., Mexico. By Alfred M. Tozzer.

Bulletin 75. Northern Ute music. By Frances Densmore.

Bulletin 76. Archeological excavations in the Ozark region of central Missouri. By Gerard Fowke.

Bulletin —. Handbook of the Indians of California. By A. L. Kroeber.

Bulletin —. Mandan and Hidatsa music. By Frances Densmore.

Bulletin —. Villages of the Algonquian, Siouan, and Caddoan tribes west of the Mississippi. By David I. Bushnell, jr.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION.

The annual reports of the American Historical Association are transmitted by the association to the secretary of the Smithsonian Institution, and are communicated to Congress under the provisions of the act of incorporation of the association.

There were published during the year the report for 1917 and volume 2 of the report for 1918. Volume 1 of the report for 1918, volumes 1 and 2 of the report for 1919, and the supplements to the reports for 1918 and 1919, entitled "Writings in American History," were in press at the close of the year.

REPORT OF THE NATIONAL SOCIETY OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The manuscript of the Twenty-third Annual Report of the National Society of the Daughters of the American Revolution was transmitted to Congress according to law in December, 1920.

THE SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION.

The editor continued to serve as secretary of the Smithsonian Advisory Committee on Printing and Publication. This committee passes upon all manuscripts offered for publication by the Institution or its branches and considers all forms of routine blanks, and such matters as pertain to printing and publication. Eight meetings were held during the year and 94 manuscripts were acted upon.

Respectfully submitted,

W. P. TRUE, *Editor.*

Dr. CHARLES D. WALCOTT,
Secretary, Smithsonian Institution.

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REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1921.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the institution and a statement of the appropriations by Congress for the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, and the National Gallery of Art, for the year ending June 30, 1921.

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1921.

The sum of \$1,000,000 deposited in the Treasury of the United States under act of Congress is a permanent fund, having been accumulated by the deposit of savings and bequests from time to time. Subsequent bequests and the income therefrom, when so required, are invested in approved securities. The several specific funds so accumulated are now constituted as follows and classed as the consolidated fund.

Hodgkins general fund.....	\$37,275.00
Rhees fund.....	156.00
Avery fund.....	18,439.80
Addison T. Reid fund.....	2,860.00
Lucy T. and George W. Poore fund.....	6,660.00
George H. Sanford fund.....	294.00
Smithson fund.....	1,468.74
Chamberlain fund.....	35,000.00
Bruce Hughes fund.....	8,741.93
Hamilton fund.....	500.00
Lucy H. Baird fund.....	1,166.58
Virginia Purdy Bacon fund.....	45,000.00
Total consolidated fund.....	157,562.05

Part of the unimproved land near the city of Lowell, Mass., forming a portion of the legacy known as the Lucy T. and George W. Poore fund, was sold during the year, and the sum of \$226.42 was realized and invested. One piece of improved real estate, at

140 East Capitol Street, Washington, D. C., forming a part of the original bequest of the late Robert Stanton Avery, is still retained by the institution and yields a nominal revenue.

During the year the following amounts were invested and added to the principal of the respective funds:

Rhees fund.....	\$39. 00
Avery fund	1, 540. 96
Addison T. Reid fund.....	710. 00
Lucy T. and George W. Poore fund.....	1, 692. 00
George H. Sanford fund.....	73. 00
Lucy H. Baird fund.....	60. 33
Bruce Hughes fund.....	386. 00
Virginia Purdy Bacon fund.....	285. 00
Chamberlain fund (balance of bequest).....	25, 000. 00
Smithson fund.....	164. 74
	<hr/>
	29, 951. 03

Since October, 1920, the institution has received from the executors of the Charles L. Freer estate stocks of Parke, Davis & Co., representing a book value of \$1,252,710. These stocks pay a quarterly dividend which is credited proportionately to the several specific purposes provided for by the testator. The total dividends received by the institution during the period from October, 1920, to the end of the year, June 30, 1921, amounted to \$25,676.

The itemized report of the auditor filed in the secretary's office confirms the following statement of receipts and disbursements:

Detailed survey of financial operations.

Ordinary receipts:

Cash balance on hand July 1, 1920.....	\$13, 304. 34
Income from Smithson fund and from miscellaneous sources available for general purposes.....	56, 796. 85
International Exchanges, repayments to the institution for specific services.....	4, 779. 47
	<hr/>
Total ordinary resources.....	74, 880. 66
	<hr/>

Ordinary expenditures:

Care and repair of buildings.....	7, 177. 37
Furniture and fixtures.....	1, 500. 97
General administration.....	27, 570. 38
Library.....	2, 954. 21
Publications (comprising preparation, printing, and distribu- tion).....	19, 533. 17
Researches and explorations.....	2, 824. 22
Invested in consolidated fund.....	164. 74
International Exchanges.....	4, 477. 63
	<hr/>
Total ordinary expenditures.....	66, 202. 39
	<hr/>

Advances and repayments for field expenses and other temporary transactions during the year:

Advances.....	\$24,322.37
Repayments.....	14,949.30
Balance.....	9,373.07

NOTE.—The several expeditions in Australia, Chile, Canada, and elsewhere will report expenditures and balances covering this difference.

RECEIPTS AND EXPENDITURES OF FUNDS FOR SPECIAL OBJECTS.

Receipts (cash received in principal and income):

Chamberlain fund.....	\$25,530.00
Roebbling fund.....	15,204.17
Loeb fund.....	1,097.80
Hodgkins specific fund.....	7,016.19
Lucy T. and George W. Poore fund.....	2,163.25
Sale of real estate.....	226.42
Lucy H. Baird fund.....	99.28
Hamilton fund.....	176.50
Rhees fund.....	42.55
Avery fund.....	1,904.00
Addison T. Reid fund.....	797.80
George H. Sanford fund.....	80.31
Bruce Hughes fund.....	802.87
Virginia Purdy Bacon fund.....	1,477.50
Charles L. Freer bequest—	
Income from stock.....	25,970.75
Special funds for installation.....	15,986.53
Harriman trust fund.....	12,164.55
Total receipts for special objects.....	<u>110,740.47</u>

Expenditures and investments:

Chamberlain fund—	
Invested.....	25,000.00
Expended for specimens.....	649.73
Roebbling fund, expended for solar researches.....	12,862.68
Loeb fund, expended.....	163.00
Hodgkins fund, expended for solar researches.....	6,916.06
Lucy T. and George W. Poore fund—	
Invested.....	1,692.00
Expended.....	372.31
Lucy H. Baird fund, invested.....	60.33
Rhees fund, invested.....	39.00
Avery fund, invested.....	1,540.96
Addison T. Reid fund, invested.....	710.00
George H. Sanford fund, invested.....	73.00
Bruce Hughes fund, invested.....	386.00
Virginia Purdy Bacon fund, invested.....	285.00
Charles L. Freer bequest—	
Expended for purposes designated by testator.....	15,026.01
Expended for building and equipment.....	15,736.89
Harriman trust fund.....	12,303.36
Total investments and expenditures of funds for special objects.....	<u>93,816.33</u>

SUMMARY.

RECEIPTS.

Ordinary income for general objects of the institution, including balance from previous year-----	\$74,880.66
Receipts in principal and from interest on funds for special objects--	110,740.47
Total -----	<u>185,621.13</u>

EXPENDITURES.

Expenditures for general objects of the institution-----	66,202.39
Investments and expenditures from special funds for specific objects-----	93,816.33
Advances for explorations, etc. (to be accounted for)-----	9,373.07
	<u>169,391.79</u>
Cash in bank on time deposit-----	5,000.00
Cash balance in Treasury and bank, June 30, 1921-----	11,229.34
Total -----	<u>185,621.13</u>

All payments are made by check, signed by the secretary of the institution, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account, except in some instances small deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The practice of investing temporarily idle funds in time deposits has proven highly satisfactory. During the year the interest derived from this source has amounted to \$1,066.67.

Your committee also presents the following summary of appropriations for the fiscal year 1921 intrusted by Congress to the care of the Smithsonian Institution.

Bureau	Appropriation.
International Exchanges-----	\$50,000.00
American Ethnology-----	44,000.00
International Catalogue of Scientific Literature-----	7,500.00
Astrophysical Observatory-----	13,000.00
National Gallery of Art-----	15,000.00
National Museum:	
Furniture and fixtures-----	\$20,000.00
Heating and lighting-----	74,000.00
Preservation of collections-----	312,620.00
Building repairs-----	10,000.00
Books-----	2,000.00
Postage-----	500.00
	<u>419,120.00</u>
National Zoological Park-----	125,000.00
Additional land for the Zoological Park-----	80,000.00
Total-----	<u>753,620.00</u>

*Statement of estimated income from the Smithsonian fund and from other sources
during the fiscal year ending June 30, 1922.*

Cash balance, June 30, 1921-----	\$11, 229. 34
Time deposits-----	25, 000. 00
Interest on fund in United States Treasury, due July 1 1921, and Jan. 1, 1922-----	\$60,000. 00
Interest from miscellaneous sources, exchange repay- ments, sale of publications, refund of advances, etc.---	13. 454. 52
Revenues to be applied to specific purposes-----	90, 525. 00
Revenues to be invested-----	7, 810. 00
	<hr/> 171, 789. 52
Total estimated for year ending June 30, 1922-----	208, 018. 88

Respectfully submitted.

GEO. GRAY,
ALEXANDER GRAHAM BELL,
HENRY WHITE,
Executive Committee.

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDING JUNE 30, 1921.

ANNUAL MEETING, DECEMBER 9, 1920.

The board met at the institution at 10 o'clock a. m.

Present: The Hon. Edward D. White, Chief Justice of the United States, chancellor, in the chair; the Hon. Thomas R. Marshall, Vice President of the United States; Senator Henry Cabot Lodge; Senator Charles S. Thomas; Representative Lemuel P. Padgett; Representative Frank L. Greene; Representative John A. Elston; the Hon. George Gray; Mr. John B. Henderson; Mr. Henry White; Mr. Robert S. Brookings; and the secretary, Mr. Charles D. Walcott.

APPOINTMENT OF REGENTS.

The secretary announced the appointments of regents, as follows:

By the speaker of the House of Representatives on January 9, 1920: Mr. Padgett and Mr. Greene to succeed themselves, and Mr. John A. Elston to succeed Mr. Scott Ferris.

By joint resolution of Congress, approved by the President on April 10, 1920, Mr. Charles F. Choate, jr., to succeed himself.

ACKNOWLEDGMENTS.

The secretary read a letter from Mr. Watson M. Freer acknowledging the resolutions adopted by the board at the last meeting on the death of his brother, Charles Lang Freer.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Judge Gray, chairman of the executive committee, submitted the following resolution, which was adopted:

Resolved, That the income of the institution for the fiscal year ending June 30, 1922, be appropriated for the service of the institution, to be expended by the secretary with the advice of the executive committee, with full discretion on the part of the secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

The annual report of the executive committee, showing the financial condition of the institution for the fiscal year ending June 30, 1920, was submitted.

After comments, on motion the report was accepted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

The secretary presented the report, as follows:

DECEMBER 9, 1920.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: Your permanent committee hereby submits the following report on the matters under its supervision for the past year:

Hodgkins fund.—Report has already been made of the allotment from this fund of a total of \$23,200 for the establishment and maintenance of a station at Calama, Chile, at which researches in solar radiation are being conducted under the direction of Dr. C. G. Abbot, assistant secretary of the institution and director of its Astrophysical Observatory.

Under an allotment of \$5,000 from this fund Dr. R. H. Goddard, of Clark College, Worcester, Mass., is continuing his work in developing certain devices to be used in connection with the study of the temperature of the higher atmospheric strata.

The Roebling donation.—Dr. Abbot decided that it would be advantageous if the Calama (Chile) station should be removed to a more satisfactory site. He planned also to establish a station in the Harqua Hula Mountains of Arizona. There being no funds of the institution available for these purposes, the matter was placed before Mr. John Roebling, of New Jersey, who generously contributed \$11,000.

Freer Gallery of Art building fund.—The condition of the fund is as follows:

Receipts	\$1,243,573.61
Expenditures	1,206,802.52

Balance	136,771.09
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The institution has received \$853,004.75 from the Freer estate as a fund provided by Mr. Freer for a permanent endowment for certain specified purposes.

The residuary legacy has not yet been received by the institution.

In reply to an inquiry, the secretary stated that the residual bequest consisted of 16,773 shares of Parke, Davis & Co. stock, estimated at present to be worth \$1,677,000. The State of Michigan had assessed an inheritance tax of over \$400,000 on the estate, but efforts were being made to have this remitted.

Avery bequest.—One piece of improved property, yielding a nominal rent, remains to be sold. The bequest now amounts to \$31,527.

Poorre bequest.—Several parcels of unimproved land near the city of Lowell, Mass., constitute the residue of this bequest. They are being sold as favorable opportunities offer. The bequest now totals \$32,588.

The Bruce Hughes bequest, to be used for founding the Hughes Alcove, is now \$10,410.

Consolidated fund.—This fund, which is made up of miscellaneous bequests and is in excess of the main fund of \$1,000,000 deposited in the Treasury of the United States, amounts to \$82,896.02.

On motion, the report was accepted.

ANNUAL REPORT OF THE SECRETARY.

The secretary submitted his annual report for the fiscal year ending June 30, 1920, with explanatory remarks.

On motion, the report was accepted.

THE SECRETARY'S SUPPLEMENTAL STATEMENT.

The secretary brought before the board a brief statement of the various activities of the Institution since the issuance of his annual report.

UNITED STATES NATIONAL MUSEUM.

One of the most notable additions to the museum will be the collection of the late Herbert Ward, sculptor, of Paris, consisting of his sculptures of African subjects, and a large collection of African ethnologica, comprising 7,000 specimens, described as a more complete collection of African material than that even of the late King of the Belgians. Mrs. Ward has agreed to present this collection under certain conditions, and the form of agreement is now being negotiated.

Probably the most interesting accession recorded in the Department of Biology since July 1, 1920, is a skeleton of a medium-sized finback whale from Florida, presented by the Miami Aquarium Association through its president, Mr. James Asbury Allison.

The beautiful collection of butterflies which the late Prof. J. P. Iddings had brought together from all parts of the world was presented to the museum by his estate. It consists of about 2,000 specimens, mostly mounted in glass-covered drawers, so arranged that they can be pulled out by the public and the contents examined. The collection will form a separate exhibit.

The Division of Plants also reports a large number of valuable accessions to the National Herbarium.

The most notable accessions received by the Division of History since the beginning of the present fiscal year have been connected with the War Collection. These include a number of objects of exceptional military interest used during the World War by the French Army and presented to the museum by the French Government.

The United States Navy Department has added a number of important exhibits to the already large and interesting series of objects illustrating the part played in the World War by the United States Navy.

The collection of objects relating to the war already deposited by the War Department has also been materially increased.

Among the more important accessions received by the Division of Mechanical Technology are:

One-quarter size model of Leonardo da Vinci's aircraft, designed in 1490 A. D. Model made in the museum from photographic copies of da Vinci's own notes.

Mechanical Navigator. A mathematical instrument for solving all problems in spherical triangles, lent by Col. Willard French through Mrs. Louise D. French.

The original United States Trade-Mark No. 1, issued by United States Patent Office, October 25, 1870, lent by Enoch A. Chase.

The Section of Wood Technology has received through Ambassador Davis, a large piece of timber recently removed from the unique hammer-beam roof of Westminster Hall, which has been undergoing extensive repairs under Sir Lionel Earle. The roof was built by Richard II, between the years 1393 and 1399, and is probably the most interesting piece of construction of any ancient roof in existence.

The American Pharmaceutical Society and the United States Pharmacopœial Convention (Inc.), have deposited in the museum several boxes of valuable historical documents consisting of manuscripts, corrected proof, and circulars, bearing on the development of the U. S. Pharmacopœia.

BUREAU OF AMERICAN ETHNOLOGY.

During the past summer the Chief of the Bureau of American Ethnology unearthed on the Mesa Verde National Park, Colo., a temple formerly used by the early inhabitants of this region in the worship of fire as a symbol of life.

It is highly probable that this lost race, which constructed a large special building for their fire cult, must have practiced most elaborate fire ceremonies, far more complicated than the rites of their few descendants, the Hopi Indians, among whom, however, the new fire rites still survive as the most elaborate ceremony in their ritual.

ASTROPHYSICAL OBSERVATORY.

Research work.—A new observing station has been established by Dr. C. G. Abbot, assistant secretary of the institution and director of the Astrophysical Observatory, on Mount Harqua Hala, in Arizona, for the purpose of carrying on solar constant measurements, the instruments used in the work having been taken from the old station on Mount Wilson, Calif.

The instruments were restandardized with the result that the secondary instruments in daily use were shown to have not altered appreciably in the many years during which they have been employed on Mount Wilson.

A new instrument called the "honeycomb pyranometer" was used for measurements of nocturnal radiation. It derives its name from the fact that it is composed of 200 deep, narrow cells, like a honeycomb, so that rays which enter the cells, although they may not be completely absorbed at first, yet by repeated reflections as they go deeper and deeper within the cells, at length attain to complete absorption and conversion into heat. These preliminary results give

promise of much advance in the measurement of rays such as the earth sends out into space at all times, which as a whole balance in their energy the energy of the sun's rays by which the temperature of the earth's surface is maintained.

Through the interest and generosity of Mr. John A. Roebling, of New Jersey, who gave the institution \$11,000 for this purpose, and through the energy displayed by the several observers concerned, the solar radiation observing station of the institution, located near the city of Calama, Chile, was removed to a much more favorable site on a mountain called "Montezuma," about 10 miles farther south, which is between 9,000 and 10,000 feet above sea level.

Details of this work will appear in later reports.

NATIONAL ZOOLOGICAL PARK.

Recent accessions.—Several valuable collections of animals have reached the park in recent weeks. A young male orang-utan, about 3 years old, together with other animals from that region, was presented by Mr. Isaac Ellison, of Singapore, Straits Settlements.

Mr. Victor J. Evans, of Washington, D. C., who has frequently shown his great interest by obtaining for the park rare animals otherwise beyond the limits of park funds, has recently purchased for the collection a fine young male Kadiak bear and a pair of beautiful Count Raggi's birds of paradise.

Attendance.—The attendance at the park continues to increase month by month. Although the fiscal year ending June 30, 1920, in the number of visitors, over 2,250,000, exceeded all records, the figures for the first four months of the current year, exceed those for corresponding months of 1919 by over 67,000. The monthly record for the first third of the current fiscal year is as follows: July, 172,500; August, 211,600; September, 190,900; October, 323,150.

EXPEDITIONS.

Smithsonian African expedition.—Thus far about 100 birds and 100 mammals have arrived, and notice of three additional shipments has been received. The collection contains three chimpanzees, besides a large number of species from South Africa, a region hitherto poorly represented in our museum.

Australian expedition.—Dr. William L. Abbott's generosity toward the institution has been continued, and an expedition to Australia financed by him is at present collecting biological specimens for the museum, while Doctor Abbott himself collected natural history and anthropological material in Haiti. Since July, 1919, he has provided \$6,000 for collecting in Australia, together with the unused balance from his previous expedition to Borneo and Celebes, which was trans-

ferred to the Australian work, which brings the total of Doctor Abbott's contributions for field-work to \$27,000. Two important collections have been received recently—one of mammals, birds, and reptiles from Siam, Annam, and Cochin China, a joint contribution from Doctor Abbott and Mr. C. B. Kloss, who collected most of the material; the other from South Australia, collected by Mr. Charles M. Hoy.

Far East expedition.—This expedition was financed by the Rockefeller Foundation to the amount of \$2,500. Early in 1920 Dr. Aleš Hrdlička proceeded to Japan and China, to make anatomical studies of the natives of those countries.

Canadian expedition.—The secretary mentioned briefly his geological work during the past summer in Alberta, Canada, in connection with the Upper Cambrian formation of that region.

FREER ESTATE MATTERS.

The secretary brought to the board's attention the clauses in the will of the late Charles L. Freer, providing funds for various purposes in connection with the Freer Gallery of Art, and for the study of the civilization of the Far East, and after full discussion resolutions covering these matters were adopted by the board.

Mr. John E. Lodge, of the Boston Museum of Fine Arts, had been placed in charge of the Gallery, with Miss Katherine N. Rhoades as temporary assistant. In view of the fact that they and their assistants were responsible for the valuable collections now being unpacked and distributed through the building, and that visitors seriously interrupted their work, it seemed best to close the building entirely to unauthorized visitors during the period of installation.

Judge Gray offered the following resolution, which was adopted:

Resolved. That the recommendation of the secretary that the Freer Building be closed to visitors during the work of installation be approved by the Board of Regents.

NATIONAL GALLERY OF ART COMMISSION.

The secretary said that in view of the steady growth of the National Gallery of Art and the position which it should assume in the development of the fine arts in America, the time had come to consider the method of providing for its administration and development.

The officers of the Smithsonian Institution should not be burdened with responsibility for the formulation of questions of policy as to purchase and acceptance of art objects, utilization and exhibition of collections, best methods of future development, securing of funds, etc. There should be an advisory commission established by the authority of the Board of Regents, which may consider not only the

local questions that would come up from time to time in relation to the National Gallery but also the broad field of art in America, and the best methods of the National Gallery cooperating with art institutions and interested individuals throughout the country and the world, in order that this phase of the Smithsonian Institution's activities shall be made most effective in *the increase and diffusion of knowledge* of the fine arts in America.

In view of the completion of the building for the Freer collections and the receipt of valuable and notable additions to the collections now deposited in the Natural History Museum, the permanent committee submits for the board's consideration the following resolution:

Resolved, That the chancellor is hereby authorized to appoint a committee of five members of the Board of Regents, with the secretary as an ex officio member, to consider the question of the appointment of a commission to be known as the National Gallery of Art Commission; and to report with recommendations to the board either at a special meeting or at its next regular meeting.

On motion, the resolution was adopted.

The chancellor appointed the following committee: Mr. Henry White, chairman; Senator Lodge; Mr. Henderson; Mr. Brookings; Mr. Greene: and the secretary.

NEW BUILDING FOR HISTORY AND ART.

The secretary spoke of the need for a suitable building for the historical and art objects now in the care of the institution, stating that last year an estimate of \$5,000 was submitted for the preparation of plans for such a building, but that no action had been taken; and that there was scarcely any probability of its receiving favorable action at the present time owing to the condition of the national finances.

He added that whenever it was practicable a request for the building should be strongly presented to the Congress.

BEQUEST OF MISS CAROLINE HENRY.

The secretary announced that under the will of Miss Caroline Henry, a daughter of Prof. Joseph Henry, the first secretary of the institution (1846-1878), an immediate bequest of \$1,000 is made to the institution, which is also to receive, with the exception of about \$7,500 in direct bequests, the remainder of the estate after the death of certain beneficiaries.

BEQUEST OF MRS. VIRGINIA PURDY BACON.

The secretary stated that by the will of Mrs. Virginia Purdy Bacon, of New York, who died in 1919, the institution was given \$50,000 to establish the Walter Rathbone Bacon (traveling) scholar-

ship for the study of the fauna of countries other than the United States. This estate can not be finally settled for some time, but the executors are prepared to transfer to the institution securities to the value of \$45,000 at the tax appraiser's valuation.

The secretary read a list of the securities comprising the amount to be turned over to the institution.

SPECIAL MEETING, MAY 27, 1921.

The board met at 10 o'clock a. m.

Present: The Hon. Calvin Coolidge, Vice President of the United States; Senator Henry Cabot Lodge; Senator Medill McCormick; Senator A. Owsley Stanley; Representative Lemuel P. Padgett; Representative Frank L. Greene; Representative John A. Elston; Dr. A. Graham Bell; the Hon. George Gray; Mr. John B. Henderson; and the secretary, Mr. Charles D. Walcott.

CALL FOR THE MEETING.

The secretary explained that under the organizing act, special meetings should be held if requested by three regents, and that the present meeting had been called at the request of Senator Lodge, Judge Gray, and Dr. Bell.

ELECTION OF TEMPORARY CHAIRMAN.

On motion of Senator Lodge, Judge Gray was elected as temporary chairman and assumed the chair.

MINUTES OF ANNUAL MEETING.

The secretary stated that the minutes of the annual meeting held December 9, 1920, had been supplied to the regents, and that a majority had indicated their approval.

On motion of Senator Lodge, the minutes were approved.

APPOINTMENT OF REGENTS.

The secretary said that under the act organizing the institution, the Vice President of the United States became a regent ex officio, and that by virtue of his election to that office, the Hon. Calvin Coolidge was now a regent.

The secretary also announced that under date of January 5, 1921, the Hon. A. Owsley Stanley, Senator from Kentucky, had been appointed a regent by Vice President Marshall.

DEATH OF THE CHANCELLOR.

Judge Gray announced the death of the Hon. Edward Douglass White, Chief Justice of the United States, chancellor of the institution, and presented the following resolutions:

Whereas: the Board of Regents of the Smithsonian Institution having received the announcement of the death, on May 19, 1921, of the Hon. Edward Douglass White, Chief Justice of the United States, regent of the Smithsonian Institution for 10 years, 8 of which he presided as chancellor;

Resolved, That the board here expresses profound sorrow at the passing away of their beloved colleague who, as statesman, jurist, and chancellor, brought always to his work that remarkable ability and high conception of duty that made him so strong an influence for good.

Resolved, That this minute be made a part of the records of the board, and that a copy of these resolutions be transmitted to the family of the late chancellor as an expression of the sympathy of the regents at the irreparable loss sustained in the death of this distinguished public servant and citizen.

On motion, the resolutions were adopted.

ELECTION OF CHANCELLOR.

Senator Lodge here offered the following resolution:

Resolved, That the vacancy in the office of chancellor caused by the death of the late Chief Justice Edward Douglass White be filled by the election of the Hon. Calvin Coolidge, Vice President of the United States.

On motion, the resolution was adopted, and the Vice President took the chair as chancellor.

REPORT OF THE COMMITTEE ON THE NATIONAL GALLERY OF ART COMMISSION.

On behalf of the committee the secretary gave a brief statement explaining the inauguration of the National Gallery of Art, its growth and importance, including the proposed National Portrait Gallery, mentioning certain gifts of paintings and art objects, and repeated his views, already expressed to the board, as to the necessity for the provision of some means for the administration of the National Gallery of Art, under the authority of the Board of Regents.

The secretary then reported that the committee had adopted a plan of organization covering the operations of the National Gallery of Art Commission, as well as a list of names of individuals proposed for membership on the commission.

Senator Lodge read in detail the plan of organization and the list of names, both of which were approved by the board.

The committee was then discharged.

INHERITANCE TAX—FREER ESTATE.

The secretary reminded the board that he had spoken at the annual meeting of the inheritance tax of over \$400,000 which the State of Michigan was about to exact from the Freer estate and of the efforts that had been made to have this canceled, but thus far without success.

NEEDS OF INSTITUTION.

The secretary brought to the board's attention the needs of the institution in the way of endowments to permit the carrying on of large projects in scientific research. He stated that the fund was small and inadequate, and among the methods adopted to bring these needs before public-spirited persons a small pamphlet has been prepared, which he brought to the board's consideration in the hope that should opportunities arise they would direct the attention of prospective donors to the usefulness of the institution.

GENERAL APPENDIX
TO THE
SMITHSONIAN REPORT FOR 1921

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the secretary, induced in part by the discontinuance of an annual summary of progress which for 30 years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1921.

THE DAILY INFLUENCES OF ASTRONOMY.¹

By W. W. CAMPBELL,

Lick Observatory, University of California.

In the great struggle through which the principal nations have passed, men and women at home labored intensively to maintain their ideals; countless millions of men fought valiantly and many millions died for the ideals of their nations. Quick results, short cuts to the end in view, the achieving of victory regardless of costs, were the order of the day. Suddenly the problems of war gave way to the problems of peace. The intensive methods of war carried over to an unfortunate degree into the days of peace. Human energy, mobilized in behalf of the nation, applied unselfishly for the good of every person in the nation, for the well-being of all the nations, was diverted in regrettable measure to promoting selfish interests. The moral exaltation of the war period was replaced in too many cases by the selfishness of individuals and organizations; by profiteering—a new word, coined to describe widespread conditions. The struggle in Russia, as the extreme case, is direct action for the sudden attainment of certain results, without due consideration for the rights of others. In all countries there are those who, seeing conditions not to their liking, in commerce, in education, in religion, in many phases of daily life, would cut and slash their way through the good, in order to uproot what, in their sight, is bad. This spirit exists in America, and throughout the world, in various degrees. Disturbances in the body politic may ensue for years or a generation by virtue of these attempted short cuts to results, but radical transformations in the social structure of the great modern nations, to endure, must find the people ready for them. The influences which prepare the way for desirable and enduring reforms are not those applied suddenly, but such as operate day and night, continuously, through long periods of time. The revolutions in Russia, in Mexico, in many parts of Latin America attract our attention, but the really serious misfortunes of those lands lie much deeper, in their bad

¹ Address on the occasion of the dedication of the Warner and Swasey Observatory, Case School of Applied Science, Cleveland, on October 12, 1920. Reprinted by permission from *Science*, December 10, 1920

social, educational, economic conditions, which are operating unfavorably upon their civilizations every day of the year.

We may well inquire what it is that bears a nation onward and upward to greater things. It is unquestionably the spirit of idealism radiating from its various activities. It is the idealism in commercial life: that part of every man's affairs which is conducted with full respect for the rights of others: that part of every man's business which would not, through its publication, injure his good name. It is the idealism of the transportation system, which interchanges commodities to mutual advantage, and acquaints one section of the world with the good things of other sections. It is idealism in banking, in farming, in the honest day's labor at an honest wage. It is idealism in the intellectual life: reverence for the truth, a desire to know the truth, and to live in harmony with the truth in one's surroundings.

A pessimist would to-day, as always, receive short shrift, yet I venture to say the world was perhaps never more urgently in need of the biblical advice, "Prove all things; hold fast that which is good." This expression of great wisdom has never been surpassed as a statement of the principles which govern men of science in their search for the truth.

The chief value of scientific method and accurate knowledge lies not in their worship by the intellectual few, not in their applications to industry, but in their influence upon the daily life of the people. The remarkable advance in civilization within the leading nations in recent centuries has been due to the daily and hourly influence of the scientific spirit, more than to any other element. Those nations which possess it are forging ahead by leaps and bounds, and those which do not are dropping out of the race. The unscientific nations are threatened with absorption by their more scientific neighbors, not so much because they do not invent or perfect the most powerful cannon, the sturdiest dreadnaught, the speediest airplane, or the subtlest submarine, but because the scientific nations are forging ahead of them in the arts of peace, in the modes of thought, in the affairs of daily life. The unscientific nations are without serious influence in the world, not because they are unwarlike—the Turks and essentially all Mohammedans are warlike enough to suit everybody—but because they are lacking in the vision and the efficiency which accompany the scientific spirit.²

History affords no more remarkable phenomenon than the retrograde movement in civilization which began with the decline of the Roman power and continued through more than a thousand years.

² This and the following paragraph have been taken, with but few changes, from one of my earlier addresses.—W. W. C.

There had once existed a wonderful Greek civilization, but for twelve or fifteen centuries it was so nearly suppressed as to be without serious influence upon the life of the European peoples. Greek literature, one of the world's priceless possessions, not surpassed by the best modern literatures, was as complete two thousand years ago as it is to-day. Yet in the Middle Ages, if we except a few scattered churchmen, it was lost to the European world. A Greek science never existed. Now and then, it is true, a Greek philosopher taught that the earth is round, or that the earth revolves around the sun, or speculated upon the constitution of matter; but excepting the geometry of Euclid and Archimedes, we may say that nothing was proved, and that no serious efforts were made to obtain proofs. There could be no scientific spirit in the Greek nation and Greek civilization so long as the Greek religion lived, and the Greek people and government consulted and were guided by the oracles. If there had been a Greek science equal in merit to modern science, think you that stupidity and superstition could have secured a stranglehold upon Greek civilization and have maintained a thousand years of ignorance and mental degradation? Intellectual life could not prosper in Europe so long as dogma in Italy, only three hundred years ago, in the days of Bruno and Galileo, was able to say, "Animals which move have limbs and muscles; the earth has no limbs or muscles, therefore it does not move;" or as long as dogma in Massachusetts, only 250 years ago, was able to hang by the neck until dead the woman whom it charged with "giving a look toward the great meeting house of Salem, and immediately a demon entered the house and tore down a part of the wainscoting." The morals and the intellect of the world had reached a deplorable state at the epoch of the Borgias. It was the re-birth of science, chiefly of astronomy, as exemplified by the work of Columbus and Copernicus, and secondly the growth of medical science, which gave to the people of Europe the power to dispel gradually the unthinkable conditions of the Middle Ages.

It has been said that we may judge of the degree of civilization of a nation by the provision which the people of the nation have made for the study of astronomy. A review of present-day nations is convincing that the statement represents the approximate truth. It is essentially true even of sections of our own country. In our first years as a nation a few small telescopes were in private hands, here and there; they were used merely for occasional looking at the stars; there were no observatories in the United States—no telescopes suitably mounted and housed for the serious study of the stars. The founding of the third American observatory, at Hudson, Ohio, about 1839, only a year or two after the completion of the second observa-

tory, at Williams College, Massachusetts, was an admirable index to the intellectual outlook of the Western Reserve.³ The laying of the cornerstone of the Cincinnati Observatory in 1843, a wonderfully ambitious institution for its day, was an event considered by Ex-President John Quincy Adams to be worthy of a hard trip, in the seventy-seventh year of his life, by rail from Massachusetts to Buffalo, by lake steamer to Cleveland, by four days of miserable canal boat to Columbus, and thence on to Cincinnati, to deliver the formal address—then called an *oration*. Adams's task was, to quote his words, "To turn this enthusiasm for astronomy at Cincinnati into a permanent and persevering national pursuit, which may extend the bounds of human knowledge, and make the country instrumental in elevating the character and improving the condition of man upon earth."

Our former slave states have to-day only one active observatory, at the University of Virginia, presented by McCormick, of Chicago. Barnard and other astronomical enthusiasts, born and grown to manhood in the south, have found their opportunities in the great northern observatories, with Olivier, of the University of Virginia, as the sole exception. What is true of astronomy in the south is true, in general, of the other sciences. This unfortunate situation is the natural product of the false, unscientific system of labor which, prevailing through many generations, taught that it is undignified for the white man to eat bread by the sweat of his own brow. Financial recovery, following 1865, has accordingly been slow. The future will correct this, for the men of the south are our blood brothers. We should be, and are, sympathetic.

Shall we try to estimate what astronomy, the oldest of the sciences, sometimes called an ideal and unpractical science, has done for mankind?

Here are some of the applications of astronomy to daily life:

1. Observations of the stars with the transit instrument, such as exists in this observatory, are supplying the nations with accurate time. Two astronomers, with modern instrumental equipment, situated on the same north and south line, may observe the stars so accurately, in comparison with the beats of their common clock, that they will agree within two or three hundredths of a second as to how much that clock is fast or slow.

2. The accurate maps of the continents and islands depend upon the astronomical determinations of the latitudes and longitudes of their salient features.

3. The sailing of ships over long courses, say from the Golden Gate to Sydney, Australia, or from New York to the Cape of Good

³The northeastern part of Ohio constitutes the "Western Reserve."

Hope, depends upon the A B C's of astronomy. Given fair skies the navigator may locate his ship in the middle of the broad ocean within a mile of its true position.

4. In America it is the habit to call upon the astronomers to fix the boundary lines between nations by observations of the stars; for example, along the 49th parallel of latitude, from Rainy Lake, Minn., westward almost to the Pacific Ocean. The uncertainty as to where this imaginary line falls upon the ground is nowhere greater than 10 or 15 feet, and it has not been found necessary by us, nor by our friends in Canada, to maintain military forts along that line.

5. The times of high and low tides, vital to mariners in entering many harbors, are determined by or from the work of the astronomers.

We do not dwell upon these responses to the immediate needs of the world, for they are unimportant in comparison with the contributions of the pure knowledge side of astronomy to progressive civilization.

Let us think of the earth as eternally shrouded in thick clouds, so that terrestrial dwellers could never see the sun, the moon, the comets, the stars, and the nebulae, but not so thick that the sun's energy would fail to penetrate to the soil and grow the crops. Under these conditions we might know the earth's surface strata to the depth of a mile or two. We might know the mountains and the atmosphere to a height of 4 or 5 miles. We might acquire a knowledge of the oceans, but we should be creatures of exceedingly narrow limits. Our vision, our life, would be confined to a stratum of earth and air only 4 or 5 miles thick. It would be as if the human race went about its work of raising corn for food and cotton for raiment, always looking down, never looking up, knowing nothing of the universe except an insignificantly thin stratum of the little earth. This picture is only a moderately unfair view of life as it existed on our planet 400 years ago, before the days of the telescope, the spectroscope, and the photographic plate, before the days of freedom of speech and thought, which came with the scientific spirit. The earth is for us no longer flat, supported on the back of a great turtle, which rests upon nothing. It is round, and every civilized person knows that it is. Exists there an intelligent man in the world whose thoughts, every day and many times a day, are not unconsciously adapted to this fact? This knowledge is a chief inheritance of the new generations. It is fundamental in our civilization. People know that the sun will rise in the morning and set in the evening, and why. A round earth, rotating upon its axis in a dependable way and revolving around the sun in exact obedience to law, are truths incomparably more sublime than the fiction of the flat earth which was pictured hazily in men's minds during pre-Copernican days. Who can estimate the value of this

knowledge to the human race? It can not be expressed with the few figures which suffice for the total of present-day financial transactions.

The stars are not lanterns hung out in the sky by angels at night, but something inconceivably grander; they are suns, hundreds of millions of suns, on the average comparable in size and brightness to our sun. Is not this ascertained fact of nature a most ennobling one to aspiring souls? Do not these facts suggest and develop becoming modesty in the minds of those who would know the truth and pattern their lives in accordance with it?

The following conversation occurred one Saturday evening in the month of June, 1912, at the eyepiece of the great telescope which Mr. Warner and Mr. Swasey constructed and erected for the Lick Observatory. I mention the time, June, 1912, because it is of the essence of the story.

Said the astronomer to the party of visitors: "The object which you will see through the great telescope this evening is the star cluster in Hercules, the finest cluster in the northern sky. Without the telescope, by naked eye, this cluster may be seen if the observer knows exactly where to look and has first-class eyes, but he will see it as apparently a single star on the limit of vision, so faint that many eyes will not see it at all. The telescope separates the cluster into a multitude of stars. If you had the time to count them, they would number fully six thousand, closely grouped in the center of the cluster, but thinning out as you approach the edges. This one object, then, which to the naked eye seems to be a single star on the limit of vision, consists of at least as many stars as the eye alone is able to see in the sky as a whole, northern and southern skies, summer and winter skies combined, and we do not doubt that long photographic exposures on the cluster, with a large reflecting telescope, would record many more than six thousand. Each of these stars is a sun and probably every one of those which you will see is larger than our sun, for we are observing merely the brightest members of the system. We do not know whether these suns have planets revolving around them or not, as the cluster is entirely too far away for us to see such planets, but planets probably exist there in great numbers: possibly there are planets revolving around all of those stars; possibly and probably there are moons revolving around the planets; and finally, there may be life, vegetable, animal, intelligent life upon those planets."

One of the visitors upon descending from the observing chair, much interested, questioned the astronomer: "Did you say those stars are all suns?" "Yes, sir." "Did you say that those stars are really larger than our sun, on the average?" "Yes, sir." "Can you

give me an idea how large our sun is?" "Well, if it were a hollow shell, of its present size, you could pour more than a million earths into it, and there would still be much unoccupied space between the earth balls." "You say there are possibly or probably planets revolving around many of the cluster stars?" "Yes, sir." "And many of those planets may be inhabited?" "Yes, sir." "Well, then, I think it does not matter very much whether Roosevelt or Taft is nominated next week at the Chicago Convention."⁴

Of course the visitor's interest in the outcome at Chicago was just as keen as ever, but he had evidently received a valuable lesson concerning man's place in nature.

The wonders of our sun are many and most remarkable and are but little known. I have referred to its enormous size. The quantity of heat which the sun is radiating into surrounding space—to the earth, to Mars, and to all other objects which intercept its rays—is stupendous and not to be comprehended by the astronomer or the man of affairs. It is, and has been, the source of all the energy upon which we draw, save only a negligible residual. A great quantity of heat is indeed stored up in the interior of the earth, but it reaches the earth's surface in such minute quantities that in all practical details of life, save to those who labor in deep mines or live near volcanoes or are interested in hot springs, this source of energy may be neglected. If this statement should be difficult to accept, let your thoughts travel to the south pole of our planet. What does the interior heat of the earth do for that region? The antarctic continent's perpetual covering of ice and snow is unaffected by it, nor does the actually enormous quantity of solar heat falling upon that continent suffice to remove the white mantle. If aught should intervene to cut off the sun's energy from the earth for one short month, the tropics would attain to a state of frigidity to which the south polar continent, as now observed, would be a rose garden in comparison.

It is the sun's heat which grows the farmer's crops, the trees of the forest and all vegetation. The coal deposits upon which we draw to-day for the running of trains, ships, factories, and rolling mills, are but the solar energy of an earlier age, compressed, transformed and preserved for our comfort and power. In the mountainous regions of our land, where water can be stored in high-level

⁴ Following the publication of this address I learned that incidents illustrating the same philosophy of life and politics occurred to Professors Frost and Barnard at the Yerkes Observatory in the heat of the presidential campaign of 1908, to Professor Wood at his Long Island observatory in the same campaign, and to others in later years. Comments similar in all essential respects are made frequently by the visiting public at Mount Hamilton. There is no reason whatever for doubting that the many reported cases are absolutely independent of each other and are merely illustrative of human nature.

reservoirs, and, passing through water wheels at lower levels, be made to generate electric power for lighting, for heating, and for the running of motors, it is the sun's energy which is transformed to meet the needs of men. The sun's rays evaporate the surface waters of the oceans, lakes, streams, and lands; the winds, generated by the unequal solar heating of our atmosphere, transport some of the water vapor to the high mountains, where it is deposited as rain or snow. It is merely the descent of these waters to the lower levels that is controlled by man and transformed into electric power for his own purposes.

It would take more than two billion earths placed side by side to form a continuous spherical shell around our sun at distance equal to the earth's distance, and thus to receive the total output of solar heat. Therefore, less than one two-billionth part of that output falls upon the earth. The earth's share of solar energy, expressed in horse-power or other familiar units, is too great to set down in figures. If you should happen to own 250 acres of land in one of the tropical deserts of the earth, you will be interested to know that your quota of the solar energy, near the middle of a summer day, is falling upon your tract of land at the rate of about 1,000,000 horse-power—more than enough heat and power to supply all the needs of this great city (Cleveland)—and this is but two-thirds of the sun's good intentions toward you, for some 40 per cent of the energy is intercepted by the atmosphere overlying your farm, and returned forthwith to outer space.

Your neighbor's tract of 250 acres is also receiving solar energy at the rate of 1,000,000 horsepower. Figuring backward, if one farm area receives 1,000,000 horsepower, and there are more than a hundred million such farm areas on the earth turned toward the sun at one time, and the whole earth intercepts less than one two-billionth of the sun's energy output, is it any wonder that sun worship became one of the recognized religions? Accurate knowledge saves us from that, but it is becoming in us to give the sun our due respect.

A great problem ahead of the scientific world is the storage of the sun's beneficent heat rays for release as needed. Astronomers are seeking intently for the sources of the sun's outpouring of energy: How can the sun maintain the supply for tens of millions of years, as it undoubtedly is doing? One important source has been found—the sun's own gravitation which tries constantly to pull every particle of its material to the sun's center—but another and greater source seems to await discovery. Does any one say, since the supply of solar energy will surely meet our needs for ten or a hundred million years, why look further for the cause? Why not

let it go at that? This selfish spirit, if applied to all subjects, would retrograde our civilization. Even the possession of the truth is not so potent for good as the desire to know the truth and the struggle to discover it. Practically, a knowledge of the origin of the sun's heat may be the key for locking up great quantities of it on summer days and unlocking it when and where needed.

Who is not interested in Mars, a planet much smaller than the earth, a little over four thousand miles in diameter, which revolves around the sun in somewhat less than two years, at an average distance from the sun 50 per cent greater than the earth's distance? Mars is literally one of the earth's brothers, and we should be sincerely interested in his welfare. Does life exist on that planet? Almost certainly there is vegetable life. We have no reason to doubt it. Certain areas of the planet change in color as the climatic seasons come and go, very much as we should expect if these colors were controlled by the natural stages of vegetable life. However, in precaution, I should guard against the drawing of the conclusion that vegetable life on Mars has actually been proved to exist. I can merely say that we see no reason to doubt its existence. Is there animal life on Mars? There probably is, but we have no positive evidence that such is the case. If the physical conditions on the planet as to water, air and soil are such that vegetable life may exist, the chances are strongly in favor of animal life also. However, I think we must leave unanswered for the present the question whether such animal life is highly intelligent. The forests of the St. Lawrence Valley and the prairies of the Mississippi Valley put on their green coats in the spring and change them to brown coats in the fall, perhaps even better before the coming of man than after his destructive influence descended upon them. If you had the means to ascend several thousand miles above your present position, and could dwell there throughout the year, you would witness the formation of a polar snow cap upon the earth early in the autumn. The southern edge of this cap would extend farther and farther to the south up to the time of midwinter. Its edge would extend well down toward the southern limits of the United States, to the Himalayas in Asia, and so on. With the coming of spring the north polar cap would decrease in size and probably disappear, save as to snows on the higher mountains and the possible ice and snows of the immediate polar region. An observer similarly situated above South America would witness similar phenomena as to the south polar regions; and these are indeed the phenomena observed on the planet Mars. The white polar caps on Mars wax and wane with the coming and going of the winter as they do upon the earth. Superficially, the Martian conditions seem not very different from the

terrestrial, though we know that the Martian atmosphere is highly attenuated, and if we were suddenly set down upon that planet's surface we should certainly suffocate for lack of air. Water is probably scarce upon that planet in similar degree. However, these facts do not militate strongly against animal life upon that planet, for such life would undoubtedly be developed with respiratory and other organs adapted to their environment. A solution of the Martian problems, as to a possible counterpart of terrestrial man on that planet, is apparently not now hopeful, but present-day failures may be the prelude to future successes, and I prefer to offer no discouragement.

The planet Venus, only a shade smaller than the earth, and but two-thirds as far from the sun as we, presents a similar but apparently more difficult problem. We know that it has extensive atmosphere, no doubt comparable with that of the earth, but concerning the presence of water we are justified in making no statement other than we remain in apparently total ignorance. If Schiaparelli was right, as he appears to have been, that Venus always presents the same face to the sun, just as the moon always turns the same hemisphere toward the earth, then one hemisphere of Venus undoubtedly remains intensively hot in perpetuity, and the other hemisphere in perpetual darkness and excessively low temperature. Can the twilight zone between the hemispheres of day and night offer abode and comfort to living forms, vegetable and animal? We have found no answer to this question, and we know not how to progress to the solution.

Are the moon and Mercury inhabited? Certainly not by such forms of life as we are familiar with, for neither object has an appreciable atmosphere. Both bodies undoubtedly suffer from extremes of heat and cold, without the protecting blanket of atmosphere with which the earth is blessed. The other planets, Jupiter, Saturn, Uranus, and Neptune, may be dismissed as uninhabitable by life forms of our acquaintance. There seems no reason to doubt that these great bodies, from four to eleven times the earth in diameter, are still devoid of solid footing for man or beast, such as the rock and soil strata afford upon the earth.

Have astronomers been able to prove that planets revolve around other suns than ours? No, the distances of the nearest stars preclude that possibility to our means in hand. Such planets would need to be manyfold brighter than Jupiter, the greatest of our planets, and our great telescopes would need multiplication many times in diameter to let us see them as attendants of their suns. We are able to prove, and have proved, however, the existence of hundreds of bodies, in distant space, whose rays of light we have not perceived. The spectrograph has shown with certainty that, of the naked-eye stars, one in four on the average is not the single star

which it appears to be to the naked eye, or when viewed in the telescope, but that it is a double sun, the two bodies revolving continuously about their mutual center of mass. These hundreds of binary systems are so far away that even under the highest telescopic magnification they blend into a common and essentially mathematical point. It is the expectation that the future, possibly the present century, will establish that one star in three, on the average, is a double solar system. It may even prove to be the truth that our solar system, consisting of one great central sun and many attendant planets, is not the average and prevailing system, but is the exception and not the rule. However, we have no good reason to doubt that tens of thousands, more probably tens of millions, of distant suns are the centers of planetary systems, and that countless planets are the abode of life. As our sun is but one of hundreds of millions of suns, it is absurd and essentially inconceivable that our planet, or two or three of our planets, should be the only bodies throughout the universe supporting life. It is vastly more probable that if our vision could penetrate to other stellar systems, lying in all directions from us, we should there find life in abundance, with degrees of intelligence and civilization from which we could learn much, and with which we could sympathize. The spectroscope proves absolutely that dozens of chemical elements in the earth's surface strata exist in our sun: that iron, the silicon of our rocks, hydrogen, helium, magnesium and so forth exist in the distant reaches of our stellar system. If there is a unity of materials, unity of laws governing those materials throughout the universe, why may we not speculate somewhat confidently upon life universal?

In the days of my youth, here in northern Ohio, the opinion prevailed throughout the community, and widely over the earth, that comets were the forerunners of wars, plagues or other forms of dire distress. Did not the great comet of 1811 herald the war of 1812, and that of 1843 the Mexican War and Donati's comet of 1858 our Civil War? Even in the twentieth century the fear that a comet may collide with the earth and destroy its inhabitants comes to the surface, here and there, every time a comet is visible to the naked eye. The findings of astronomers concerning these visitors to our region of space have taught that we have nothing to fear from them, and that their close approaches may be welcomed, for they are interesting members of our sun's family. They revolve around our sun as the planets do, and render unto it homage and obedience. It is undoubtedly true that the earth has plunged through the tails of comets many a time and without appreciable effects upon our health and happiness. In fact, the inhabitants have at the time been blissfully unaware of the passage. It is true that a collision of the con-

densed head of a comet with the earth is not impossible; it may some time occur; but comprehensive studies of this question, based upon observational data concerning many of these bodies, lead indubitably to the conclusion that we must not expect these collisions to occur, on the average, more than once in 15 or 20 million years. The so-called shooting stars, which we have all observed in the night sky, are in many cases, perhaps in all, though we do not know, the burning of minute pieces of comets which have disintegrated and disappeared as comets forever from our sight. Colliding with the earth, rushing through the upper strata of our atmosphere with speeds up to 40 or more miles per second, the frictional resistance of the air heats them to the burning point, and they are turned into ashes and the vapors of combustion. A very few get through to the earth's surface and are found and placed in our museums. It is not certain that any of those in the museums are parts of disintegrated comets, but some of them probably are. The number of small foreign bodies which collide with our planet every day is very great; a conservative estimate is 20,000,000. Except for our beneficent atmosphere man would suffer many tragedies from the bombardment. There is reason to believe that the earth is growing larger very slowly, from these accretions, and this may have been the process by which the earth grew from a small nuclear beginning up to its present size.

Astronomers have determined that our solar system is very completely isolated in space. We are widely separated from our neighbors. I shall not try your patience by quoting the tremendous distances in miles, for they are incomprehensible to all of us. Rays of light sent out by the sun require a little more than eight minutes to reach the earth. The outermost known planet in our system, Neptune, would be reached in four hours and a half. Rays of light leaving the sun at the same time and traveling at the same rate, 186,000 miles per second, must travel continuously during four years and a half to reach our nearest known neighbor in space, the bright double star, Alpha Centauri. If the distance from the sun to the earth is 1, the distance to our outer planet is 30, and the distance to Alpha Centauri is 275,000. There appears to be an abundance of room in the great stellar system to meet the requirements of all. The spectrograph attached to the Lick telescope has determined that our sun and its family of planets is traveling through the great stellar system with a speed of $12\frac{1}{2}$ miles per second, equivalent to 400,000,000 miles per year. The earth is certainly hundreds of millions of years in age, the sun is no doubt at least as old, and the early youth of the earth was lived, not where we now are, but far

elsewhere in the stellar system; and its future journeyings will lead to quite other points of observation.

The question of greatest interest to present-day astronomers is that of stellar systems other than our own. The chances seem strong that the hundreds of thousands of spiral nebulæ known to exist, in very distant space are other and independent systems of stars, many of them perhaps containing as many stars as our stellar system. In other words, our stellar system may be but one of hundreds of thousands of isolated stellar systems distributed through endless space. This is not an established fact, but the evidence seems to run in its favor.

I have referred to some of the problems and results of astronomical science. The list of interesting items is a long one, but available time has its limits. In brief, it is the astronomer's duty to discover the truth about his surroundings in space, and make it a part of the knowledge of his day and generation. The ultimate and real value of his work lies in its influence upon the lives of the people of the world, in the change for the better which it induces in their modes of thought, and in the impulse which it gives to an advancing civilization.

Would that the attractions of the sky to the average man were more potent. It is a curious comment upon the attributes of city life that hundreds of thousands of people, especially children, in London and Paris, in the darkness which gave them semiconcealment from the enemy's destructive airships, should have obtained their first real vision of the starry heavens. What must have been their sensations? On the other hand, those who can view its beauties and wonders are prone to neglect it; to look down instead of up. Emerson has said somewhere in his immortal essays that if our sky should be clear of clouds but one night in a century, the people of this globe would look forward to the rare event, and not only prepare to behold its beauties themselves, but make sure that their friends far and wide were likewise minded. How the beauties of the night sky would surpass the expectations of the most lively imagination! The wondrous vision would be the prevailing subject of conversation for years and years, and the repetition of the vision, 100 years later, would need no advertising.

Our knowledge of the heavens is in its infancy. We have but made a start upon the discovery of the truth about the stars, and the results of astronomical research are not so widely known amongst the people as they should be. This splendid institution, The Warner & Swasey Observatory, presented by men who were masters in telescope and observatory design and construction, by men who have thought much of relative

values in life, this institution has a field of great usefulness lying before it. In their administration of the generous gift, the trustees, the president and the faculty of the Case School of Applied Science, whether for research, for school instruction or for community education, will have the sympathetic interest of astronomers, of all lovers of the truth. This observatory may assist in the solution of important problems concerning the universe of which we form a part. The universities, the colleges, and the technical schools of our country, and of other countries, are graduating every year many hundreds of young men, ready to start upon the more serious phases of their lives, who can tell us all about the lights in our houses, but not one word about the lights in our sky. This institution will do its quota in approximating to a liberal education. The casual visitor who enters its portals in search of knowledge, yea, the passerby in the street who merely sees a dignified and purposeful observatory set upon a hill, will have his thoughts directed to higher levels.

COSMOGONY AND STELLAR EVOLUTION.¹

By J. H. JEANS, F. R. S.

I. THE EVOLUTION OF GASEOUS MASSES.

The progress of observational astronomy has made it abundantly clear that astronomical formations fall into well-defined classes: they are almost "manufactured articles" in the sense in which Clerk Maxwell applied the phrase to atoms. Just as atoms of hydrogen or calcium are believed to be of similar structure no matter where they are found, so star-clusters, spiral nebulae, binary stars are seen to be similar, although in a less degree, no matter in what part of the sky they appear. The problem of cosmogony is to investigate the origins of these comparatively uniform formations and the process of transition from one class to another.

In attacking this problem the cosmogonist of to-day stands upon the shoulders not only of previous cosmogonists, but also, what is of even greater importance, upon the shoulders of the brilliant and industrious astronomical observers of the past century. We shall find it convenient to take as our starting point the most famous theory of cosmogony ever propounded—the nebular hypothesis of Laplace—and we shall examine to what extent it remains tenable in the light of modern observational and theoretical research.

Laplace's hypothesis referred primarily to the genesis of the solar system, which he believed to have originated out of a hot nebulous mass that shrank as it cooled. The nebula was supposed to be in rotation, so that the principle of conservation of angular momentum required that as the mass cooled its speed of rotation should increase. It is well known that a mass either of gas or of liquid in rotation can not rest in equilibrium in the spherical shape which would be assumed in the absence of rotation. If the rotation is very slow the equilibrium shape will be an oblate spheroid of small eccentricity. As the rotation increases, the ellipticity will increase, but it is found that the spheroidal shape is soon departed from. Laplace believed, as a matter of conjecture rather than of reasoned proof, that with con-

¹ Lectures delivered at King's College, London, on May 2 and 10, 1921. Reprinted by permission from *Nature*, June 30 and July 7, 1921.

tinually increasing rotation a mass of gas would in time reach a stage at which it could no longer exist as a single continuous mass. When this stage was reached he believed that a ring of particles would be discharged from the equator through the centrifugal force of rotation outweighing the centripetal force of gravitation. The mathematical researches of Roche (1873) provided some support for this general conjecture, and more recent investigations put its general accuracy beyond doubt.

It is found that the changes of shape which accompany increase of rotation are, in their general features, the same for all masses, whether gaseous or fluid, provided only that there is sufficient central condensation of mass. When the rotation becomes so great that the spheroidal figure is departed from, the equator of the mass is found to pull out into a pronounced edge, which ultimately becomes perfectly sharp (see fig. 1). The mass has now assumed a lenticular shape, and any further increase of rotation results in matter being discharged from this sharp edge. The lenticular shape is retained from now on, the sharp edge acting like a safety valve and emitting just so much matter as is necessary to carry off the excess of angular momentum beyond the maximum which can be carried by the central mass. Figure 1 shows the configurations of the lenticular figures

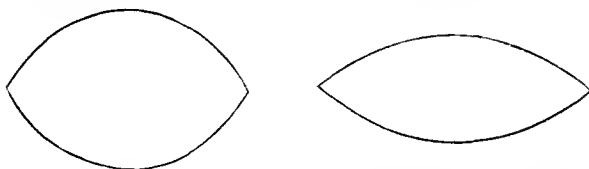


FIG. 1.—Figures of equilibrium for rotating masses of gas.

for masses of gas in adiabatic equilibrium, in which γ (ratio of specific heats) has the extreme values 1.2 and 2.2, respectively. Other calculated lenticular figures show generally similar shapes. With a further increase of rotation beyond that for which these curves are drawn, the figures would remain unaltered save for the addition of a distribution of matter in the equatorial plane—the matter already thrown off from the sharp edge of the lens.

If gaseous stars assume these forms our telescopes refuse to reveal them. Even in the most powerful telescopes the stars remain infinitesimal points of light; the only bodies which show any observable shape are the nebulae. It is highly significant that a number of these exhibit precisely the lenticular shape just described. This is in most cases accompanied by a distribution of matter in the plane through the sharp edge of the lens. A number of such nebulae have been found by direct spectroscopic observation to be in rotation about an axis perpendicular to this plane. Thus there is very strong justification for supposing that these nebulae are masses of gas or other mat-

ter with high central condensation behaving precisely as imagined by Laplace—rotating and throwing off their excess of angular momentum as they cool by the ejection of matter in their equatorial planes.

There is, however, almost incontrovertible evidence that the nebulae which have just been described are nothing but ordinary spiral nebulae seen edgewise, for observation discloses a continuous sequence of nebulae the shapes of which bridge completely the gap between the lenticular nebulae, in which we are looking at right angles to the axis of rotation, and the familiar spiral nebula in which we look approximately along this axis. The characteristic nebula shows a nucleus which we can now identify with the lenticular figure demanded by theory, having two arms emerging symmetrically from opposite points of the nucleus. If our identification is correct these arms must be formed out of the matter already discharged from the nucleus. It has in point of fact been found by van Maanen and Kostinsky that the matter in the arms appears to be in motion approximately along the arms and in the outward direction.

Any external gravitational field, whether of the universe as a whole or of neighboring stars or nebulae, would produce a tidal field similar to that produced by the sun and moon on the surface of our earth, a field specified mathematically by a second harmonic. This field, no matter how small in amount, would suffice to destroy the exact circular shape of the "equator" of the nucleus and so would concentrate the emission of matter at two opposite points on this equator. Thus it is easy to understand why the nebulae, as a rule, exhibit two symmetrical arms emerging from antipodal points. It is very much less easy to understand why these arms should be of the universal spiral form—the absence of any explanation of this form must be regarded as a serious drawback to our interpretation of the spiral nebulae. It is readily proved that the ejected filaments of matter, whatever the shape they assume, could not remain of uniform line-density. Such a distribution of density would be unstable, and it can be proved that nuclei would form at approximately equal distances, around which the matter of the arms would condense. In this way it is possible to explain the nuclei and condensations which are observed in the arms of the spiral nebulae. It is also found possible to calculate the amount of matter which will condense around each nucleus; the mass of each is found to be of the order of magnitude of the known masses of the stars.

In this way I have been led to conjecture that the spiral nebulae are whirling masses of gas which, owing to their rapidity of rotation, throw off gaseous stars much as a "Catherine-wheel" firework throws off sparks. If so, the condensations in the arms of these nebulae are stars in the process of birth. Dynamically the mechanism is almost

identical with that imagined by Laplace as resulting in the birth of systems of planets and satellites, but on a far more stupendous scale. The final product of the chain of events we have been considering must be some type of star cluster—perhaps a globular star cluster, or possibly an “island universe” similar to our galactic system. The difficulties in the way of an exact mathematical investigation into the history of the ejected gas, as the filaments condense around nuclei and as these form stars and begin to move as detached bodies, are enormous. On the other hand, the determination of the final steady states possible for a system of stars created in this way is quite simple. There is found to be only one type of final steady state possible for a system of stars created out of a rotating mass of gas, and this shows exactly the features presented by the system of stars of which our sun is a member. The system of stars will be of a flattened shape, symmetrical about the plane of greatest cross-section (the galactic plane in our system); the velocities in any small region of space will not be distributed at random, but will show a preference for two opposite directions (“star streaming”); these directions will be parallel to the plane of symmetry and perpendicular to the radius to the center of the system. This last direction is that given by Charlier for the direction of “star streaming” in our system. Our system passes all tests for having been born out of a spiral nebula the plane of which was what is now the plane of the Milky Way; indeed, Easton and others have claimed to find traces of the two spiral arms still surviving in the distribution of stars in this plane, as though the final steady state had not yet been reached.

[*Added February, 1922.*—The test, however, is not a very stringent one. For if a number of stellar systems, each one of which had been born out of a rotating nebula in the way we have imagined, were to fall together as the result of gravitational action and unite into a single giant system of stars, it can be shown that this giant system, if or when it attained a steady state, would show precisely these same properties. Thus our test leaves it an open question whether our universe has been born out of a single nebula or out of a great number of smaller nebulae. It probably accords best with present observational knowledge to suppose that our universe has been formed by the intermingling of a large number of separate star groups each of which is the product of a single spiral nebula. The globular clusters may well be groups of this type which have not yet mingled with the main mass of stars, while the moving star clusters, such as the Taurus cluster, the Ursa-major cluster, and possibly also the whole system of the B-type stars, may be groups, or the remains of groups, which have fallen into the main mass and become inter-

mingled with it spatially while yet preserving sufficient uniformity of motion among their members to enable us to recognize them as distinct groups of stars.]

Let us now turn to a study of the lives of individual stars. To the naked eye the stars appear as mere points of light of varying brightness. The telescope adds little except possibly differences of color. The spectroscope appears at first to add a wealth of new information, but a detailed study of stellar spectra discloses the unexpected fact that all stellar spectra, apart from a few exceptions, fall into one single linear series. Photographs of the spectra of all stars, in which varying exposures have been made to compensate for varying brightnesses, can be arranged uniquely in a consecutive order in which each spectrum differs only imperceptibly from its neighbor. All the complicated diversities of stellar spectra appear to be determined, in the main, by one single variable. This is believed, with good reason, to be the temperature of the star's surface.

Positions on this linear series are specified by reference to six selected points denoted by the letters B, A, F, G, K, M, in this order. The order given is that of decreasing surface temperature. Stars having B spectra are of bluish color with a surface temperature of $10,000^{\circ}$ C. or more. Stars of type M are red with a surface temperature of only $3,000^{\circ}$ C. Our sun is of type G, with a surface temperature of about $6,000^{\circ}$ C.

We might also arrange the stars in order of brightness. The distances of many stars are known, and for these we can calculate the "absolute brightness" or "luminosity"—i. e., the amount of light omitted as compared with our sun. Since the masses of the stars are all approximately the same, it might be expected that the order of "luminosity" would prove to be substantially the same as that of surface temperature, but this does not prove to be the case. Eight years ago it was found by Hertzsprung and H. N. Russell that the red M stars fell into two widely different classes, one class having abnormally high luminosity, and the other abnormally low. The ratio of luminosities in the two classes is of the order of 10,000 to 1, and since the surface temperatures are the same, this ratio must imply a corresponding ratio in the areas of the radiating surfaces. Thus the two classes of M stars must have volumes in a ratio of about 1,000,000 to 1, for which sufficient reason they have been designated "giants" and "dwarfs." From a comprehensive discussion by Russell, recently confirmed by Adams and Joy, it is clear that the demarcation between "giants" and "dwarfs" extends, although with diminished intensity, through the types K, G, and F, while at types A and B the classes coalesce.

Lately Shapley, by determining the distances of the globular clusters, has greatly increased our knowledge of stellar luminosi-

ties, and has calculated the individual luminosities of 1,152 giant stars in clusters. If we plot the logarithms of the luminosity (or the absolute magnitude) against spectral type as in figure 2, the vast majority of Shapley's 1,152 stars are found to lie within the belt marked "giants," while of the stars previously discussed by Russell and by Adams and Joy nearly all lie either within this belt or within that marked "dwarfs." In this diagram a few typical stars have

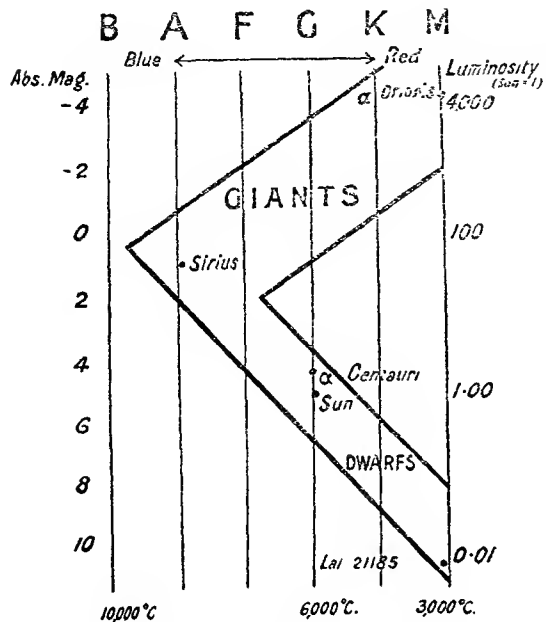


FIG. 2.—Luminosity-temperature diagram.

been marked. The stars α Orionis and our near neighbor Lalande 21185 are examples of giant and dwarf red stars. The diameter of the former has recently been found by direct measurement to be about 300 times that of our sun, corresponding to a density of the order of at most one-thousandth of that of atmospheric air; the latter has a luminosity only 0.009 times that of the sun, and probably a mean density comparable with that of the earth. Our sun and our nearest stellar neighbor, α Centauri, are marked as typical dwarfs of type G, and Sirius is a representative A-type star.

From the known luminosity and surface temperature of any star it is easy to calculate its surface and so its density. Giants of types G and K are found to have densities of the order of 0.004 and 0.0005, respectively, agreeing with the known densities of binary stars of these types. Sirius, with a luminosity of forty-eight times, and a surface temperature about one and a half times, those of our sun, must have a surface nine times as great. Its mass is 3.4 times the solar mass, so that its density must be about 0.2. In general it is found that all giant stars must be gaseous, of density so low that the ordinary gas laws will be approximately obeyed. Dwarf stars may be gaseous or liquid or solid, but, if gaseous, they are so dense that the gas laws will be nowhere near the truth. It is now easy to see why, in the giant stars, increase of temperature and density go together; this is merely a consequence of Lane's law. But the dwarfs may be

thought of as approximating rather to masses of fixed dimensions, and for these the luminosity falls off as the temperature decreases.

Our sun radiates light at a rate of about 2 ergs per second per gram of its mass. Gravitational contraction, as Lord Kelvin showed, could provide energy at this rate for only about 20,000,000 years, and radio-active and chemical energy could only slightly lengthen this period. For a giant star, radiating at 1,000 times the rate of the sun, the maximum period would be only a few thousand years. This period is far too short, and it is now generally accepted that, so far from gravitation and known sources of energy providing the whole of a star's radiation, they can provide only an insignificant fraction. Energy of adequate amount can originate only from subatomic sources, as, for instance, from internal rearrangements in the positive nuclei of the atoms or from the transformation of a small fraction of the star's mass into energy. It is a matter of simple calculation to show that all other stores of energy in a star can constitute only an insignificant reservoir of energy which, unless continually replenished from subatomic sources, would be exhausted in, astronomically, a moment. Thus the rates of radiation and of generation of subatomic energy must be practically equal, and the luminosity of a star will be determined by the latter rate at any instant.

We may now think of the evolution of the stars as represented by the march of a vast army through our diagram (fig. 2), the individuals keeping, for the most part, within the marked belt. Each individual takes his marching orders from the supply of subatomic energy, and so long as we remain in ignorance of the exact source and nature of this we can not be certain whether the motion of the army is up or down, or even that it is all in the same direction. But if we are right in conjecturing that the stars were born out of a nebula of very low density, the order of march will be from low density to high; our army will be marching downwards in the diagram. Its tail, except for a few stragglers, is about at absolute magnitude -4 , its head is lost in darkness. In the next lecture we must study the incidents which may occur during the march of this army of stars.

II. THE EVOLUTION OF STELLAR AND PLANETARY SYSTEMS.

In the last lecture we followed up, so far as is permitted by modern theoretical and observational research, the train of ideas on which Laplace had based his nebular hypothesis. Theoretically we found that a shrinking mass of rotating gas ought in time to assume a lenticular shape, after which further shrinkage would result in the ejection of matter from the sharp edge of the lens. It is suggested that the spiral nebulae form instances of this process, the spiral arms being the ejected matter and the central nucleus the remnant of the original rotating mass of gas. The spiral arms are observed to

break up into condensations, a process of which a theoretical explanation can readily be given. But on inserting approximate numerical values it is found that each condensation must have a mass comparable with that of a star. In the spiral nebulae we are watching, not the birth of planets, which Laplace attempted to explain by his nebular hypothesis, but the birth of the stars themselves. The process is, in its main outlines, identical with that imagined by Laplace, but is on a more stupendous scale.

The separate stars when set free from the parent nebula are themselves shrinking and rotating masses of gas; they may be thought of as small-scale models of the nebula which gave them birth. We naturally inquire whether the process of evolution of these small-scale models will be the same as in the parent nebulae. The answer is provided by a mere inspection of the physical dimensions of the formulæ which govern the dynamical processes of evolution. It is found that, as regards the central mass of lenticular shape, the small-scale model operates precisely like the bigger mass. Any rotating mass of gas, provided only that it is sufficiently great to hold together under its own gravitation, will in due course assume the lenticular shape and discharge matter from its equator. But as regards the ejected matter, the small-scale model does not work in the same way as the bigger mass. If the matter ejected from a big mass forms a million condensations, the matter ejected from a small mass of one-millionth part of the size will not form a million tiny condensations—it will form only one condensation, and will, moreover, form this one only if other physical conditions are favorable. In actual fact, when regard is had to numerical values, it is found that other physical conditions are not favorable. The matter will be ejected at so slow a rate that each small parcel of gas will simply dissipate into space without any gravitational cohesion at all. Some molecules will probably escape altogether from the gravitational field of the central star, while the remainder will form merely a scattered atmosphere surrounding the star. For this reason, in addition to others, the conception of Laplace does not appear to be capable of providing an explanation of the genesis of planetary systems.

So far we have studied the way in which a mass of gas would break up under increasing rotation. As a matter of theoretical research it is found that a mass of homogeneous incompressible substance, such as water, would break up in an entirely different fashion. It is further found that there are only these two distinctive ways in which a break-up can occur, so that if a mass, the rotation of which is continually increasing, does not break up in one way it must break up in the other. As a star, from being a mass of gas of very low density, shrinks into a liquid or plastic mass of density perhaps

comparable with that of iron, it passes through a critical point at which there is a sudden swing over from one type of break-up to the other. This critical point occurs when the density of the star has become such that the ordinary gas laws are substantially departed from throughout the greater part of the star's interior. This density is, however, precisely that which marks the demarcation between giant and dwarf stars. Thus the general conclusion of abstract theory is that a giant star will break up under increasing rotation in the way we have already had under consideration, but that a dwarf star will break up in the same way as a homogeneous incompressible mass, such as a mass of water.

The discovery of the method of break-up in this second case forms one of the most difficult problems of applied mathematics. In spite of the labors of many eminent mathematicians, among whom may be mentioned Maclaurin, Jacobi, Kelvin, Poincaré, and G. H. Darwin, the problem is still far from complete solution. It is found that, as the rotation of a homogeneous mass increases, the boundary remains of exact spheroidal shape until an eccentricity of 0.8127 is reached, at which the axes are in the ratio of about 12:12:7. With a further increase of rotation the boundary ceases to be a figure of revolution; it becomes ellipsoidal and retains an exact ellipsoidal shape until the axes are in a ratio of about 23:10:8. Beyond this it is impossible for the mass to rotate in relative equilibrium at all, and dynamical motion of some kind must ensue. At first a furrow forms round the ellipsoid in a cross-section perpendicular to the longest axis, but the cross-section in which the furrow appears does not divide the figure symmetrically into equal halves. The furrow deepens, and at this stage the problem eludes exact mathematical treatment. It appears highly probable, although it cannot be rigorously proved, that the furrow will continue to deepen until it separates the figure into two unequal masses. On the assumption that this is what would actually happen we may conjecture that the process we have been describing is that of the fission of a single star into a binary of the familiar type, but the conjecture is beset by many difficulties. To mention one only: if we have truly described the history of a star before fission, the star ought during a moderate part of its life to possess an ellipsoidal figure, and as this rotated the light received from the star ought to vary to an extent which just before fission might amount to 0.9 magnitude. Yet I believe there are only three known stars whose variation of light is such as could possibly be accounted for by an ellipsoidal surface, and even in these cases the interpretation is doubtful. On the other hand, very considerable reassurance is provided by the researches of Russell on multiple stars. After a star has broken into two

parts by fission both parts will continue to shrink, so that either or both may in turn again break up, and a triple or quadruple system be formed. Russell finds that in a multiple system which has been formed in this way the distance between the stars formed by subsequent fissions can not be more than a small fraction, at most about one-fifth, of the distance between the pair generated by the original fission. A mere glance at a catalogue of multiple stars will show that this condition is fulfilled by the majority of observed systems. On account of foreshortening the apparent separations will not always appear to conform to the rule, but Russell has shown, as the result of a careful statistical discussion, that the exceptions agree, both in kind and in number, with what might be expected from foreshortening.

We have now traced out the life-history of a rotating and shrinking mass from beginning to end, from its start as a gaseous mass of very low density, through its assumption of a lenticular shape and its first break-up as a spiral nebula, through its subsequent condensation into separate stars, to their final fissions into binary and multiple systems. The picture has been distressingly incomplete, and it can not be denied that the story is beset by many difficulties and uncertainties. The mathematical investigation is far from perfect; gaps in theory have frequently been bridged by nothing more substantial than conjecture; in many cases there has been room for grave doubt as to the identification of observed formations with those predicted by theory; in one instance at least a formation predicted by theory, the ellipsoidal star, is practically unknown to the observing astronomer. But, after allowing for all imperfections, we have a tolerably complete knowledge, so far as the main outlines are concerned, of the whole chain of configurations which will be assumed in turn by the rotating shrinking mass of Laplace, and on this chain there does not appear to be any room for the solar system.

Apart from this, there are weighty reasons for thinking that our system has not been formed as the result of a rotational break-up. The angular momentum of a system remains constant during a process of breaking up, and, as was pointed out by Babinet in 1861, even if the whole angular momentum of the solar system were now concentrated in the sun it would still have less than a quarter of the angular momentum requisite for breaking up at its present density. Except in the improbable event of the solar system, since fission, having been robbed by a passing star of by far the greater part of its angular momentum, its rotation can never have been sufficient to cause a break-up. Clearly there is a case for examining whether some other agency can not produce a system such as ours.

The sun and moon, as we know, raise tides on our earth the height of which forms only an inappreciable fraction of the earth's radius. If our earth were replaced by a mass of liquid or gas of low density the fraction would be greater, varying inversely as the density of the mass. If the sun and earth were placed much nearer to one another than now the tides would be increased in the ratio of the inverse cube of their distance apart. We can easily imagine conditions under which the heights of the tides would be comparable with the radius of the earth, and here the simple formulæ which the mathematician uses to calculate the heights of terrestrial tides become useless. The general investigation of the succession of shapes which will be assumed by a gaseous or plastic mass as the tidal forces on it continually increase presents a difficult but not altogether intractable problem for the mathematician.

It is found that the tides will be of the general type with which we are familiar on the earth until a certain critical height of tide is reached. This critical height is comparable with half the radius of the mass, being greater or smaller according as the mass is of more or less uniform density. After this critical height has been passed, there is no longer a configuration of equilibrium under the tidal forces. Dynamical motion ensues, and the general nature of this motion will consist in the ejection of two arms or jets of matter, one towards the attracting mass and one, which may be smaller, or may be absent altogether, in the exactly opposite direction. If the tide-generating forces should be suddenly removed at this stage the jets would, of course, fall back into the mass from which they emerged, and this would in time resume its spherical form. But if the tidal forces persist, the jets will continue to be thrown out, and it can be shown that a continuous distribution of density in these jets would be unstable, just in the same way, and for similar reasons, as in the case we previously discussed of the jet thrown out from a rotating mass of gas. Condensations would form in the jets, and ultimately the jet would break up into separate detached masses.

According to the tidal hypothesis of the origin of the solar system, the sun was at some past time subjected to intense tidal forces from a passing star, the sequence of processes we have just described took place, and the emitted jet broke into fragments which are our present system of planets. From the mathematical investigation on which this hypothesis is based, it appears that the fragments would each be comparable in mass with the original sun if the matter of the sun had been of approximately uniform density, but would be very small by comparison if the sun had been gaseous with high central condensation. The smallness of the masses of the planets in comparison with that of the sun must, therefore, be taken as in-

dicating that the sun was in a gaseous state with high central condensation when the planets were born. The jets of matter thrown out would also be gaseous, but would rapidly cool in the process of ejection, and might soon liquefy or even solidify. It can be shown that the planets which would be formed out of the middle portion of such a jet ought to be much more massive than those formed near the ends, and this may possibly provide an explanation of the comparatively great masses of Jupiter and Saturn. We imagine that the planets at first described orbits under the combined gravitational action of the sun and the passing star by which the cataclysm was caused, but as this star receded they were left revolving, as at present, around the sun. During their earlier motion they may themselves have been broken up by the tidal action of one or both of the big masses present, and such a process may explain the origin of the satellites of the planets.

Such, in its main outlines, is the tidal theory of the genesis of the solar system. So far as can be seen, a vast amount of further mathematical research is needed before it can be either definitely accepted or finally condemned. For myself, I find it more acceptable than the rotational theory, or any other hypothesis so far offered, of the origin of the solar system. Time does not permit of a discussion of its difficulties, but I may perhaps conclude by stating what seem to me to be its main advantages over the rotational theory.

(1) It escapes the well-known criticism of the rotational theory that the present angular momentum of the solar system is too small to be compatible with a previous rotational break-up, and I do not know of any similar quantitative criticism which can be brought against the tidal theory.

(2) The solar system is arranged with reference to two planes—the invariable plane of the system, which contains the orbits of the outer planets, and a second plane inclined at about 6° to the former plane, which contains the sun's equator and the orbit of Mercury. A system which had broken up by rotation alone ought to be arranged symmetrically about one plane—the original invariable plane of the system. On the tidal theory the two planes of the solar system are readily explained as being the plane in which the tide-raising star moved past the sun, and the original plane of the sun's rotation.

(3) Theoretical investigations suggest that there is only one possible end for a rotating system, namely, a binary or multiple star of the type familiar to astronomers, and it is quite certain our system is not of this type. Similar investigations on tidal action suggest that the final end of a system broken up by a tidal cataclysm ought to show many of the features of our present solar system.

THE DIAMETERS OF THE STARS.¹

By A. DANJON,
Astronomer at the Strasbourg Observatory.

[With 1 plate.]

Stellar astronomy is now taking its place definitely in the ranks of sciences. For 20 to 30 years the census of the starry heavens grew, star after star, nebula after nebula, without any definite bond, any generalization, any law emerging showing the connections existing among their number. Astronomers seemed yet in the dark as to any general plan of the universe. Similarly before Ptolemy and Hipparchus, except for the existence of the planets, the plan of the solar system was not known. The astronomers of Alexandria made their names forever illustrious in showing that the planets were subject to laws. They gained the first approximation to the plan of the solar system. True, it fell to the lot of others, of Kepler, of Newton, to give a more thorough solution of the problem and a deductive status to planetary astronomy. But without their predecessor's steps, how halting would have been their progress.

The solving of the problems of sidereal astronomy began when physics produced the appropriate tools. The elder Herschel had marked out the way, helped by his great ingenuity but handicapped by paucity of instrumental means. The American school of astronomers has put on foot the work which we of to-day admire both for its rich promise and the germs of truth it contains. Truly hypothesis plays a preponderant part in the interpretation of the observations. We are yet far from the completion of a magnificent logical structure such as planetary astronomy has gained. A mathematician would be ill at ease before the numerous publications which bring us the echo of the discoveries gleaned from the stellar universe. At present astronomers are garnering facts; the near future may bring the Newton or the Kepler who will place them in their proper

¹ At a general assembly of the Société Astronomique de France Professor Michelson described his method of measuring stellar diameters. A survey of some related subjects is useful as an introduction to his work.

Translated by permission from *L'Astronomie*, November and December, 1921.

relationships. In a few generations doubtless the time will come to use the rich harvest of observations now patiently being accumulated. Then in its turn sidereal astronomy will become clear, logical, deductive. At least it is a patriotic wish that it may be so, for it is a task especially suited to the French genius.

EQUIVALENT DIAMETERS.

The direct measurement of star diameters fills a whole chapter in astronomy till now rather hypothetical. A long time ago all hope had been lost of detecting the disks of the stars with the ordinary instruments of our observatories. At the focus of our telescopes, diffraction spreads the light received from a luminous point into a circular diffuse spot surrounded by rings. Since such a spot is much larger than the true geometrical image of a star, it is impossible to distinguish between the image of a star and that of a point. If we try to measure with a micrometer the angular diameter of a star, the value obtained will have no relationship with the true dimensions. The measurements will give merely the diameter of the diffraction spot which depends solely on the aperture of the objective of the telescope.²

It is true, we can measure extraordinarily small relative displacements of stars, of the order of a few hundredths of a second of arc. For instance, the annual parallax³ has long since been determined. The two problems are really very different in nature and difficulty. We can determine with great precision the center of the diffraction spot and its displacements, although some special device is necessary to force it to deliver up its secret of the true nature of the luminous source.

The measurement of stellar diameters is therefore a difficult task to approach since we are unable to produce true images of stars by any direct means. Consequently, for some time we have exercised our ingenuity in avoiding this difficulty by evaluations more or less hypothetical. Sometimes the evaluations have rested on solid foundations. We know, for example, the fruitful researches relative to eclipsing variables, but the information thus gathered does not suffice for an exhaustive study. Let us leave aside this aspect of our subject, very interesting though it be in itself, in order to consider a general method based upon the comparison of the relative brightness of stars and the sun.

² The diameter of the diffraction spot is inversely proportional to that of the objective. An aperture of 12 centimeters (5 inches) gives a spot about two seconds of arc (2") in diameter. An aperture of at least 5 meters (16 feet) would be necessary before the disk of the greatest star (0."05) would begin to be appreciable.

³ The annual parallax of a star is the angle which the radius of the earth's orbit about the sun occupies as seen from the star.

The apparent intensity of a luminous source depends upon two factors; its intrinsic brilliance and its surface. If two stars have the same intrinsic brilliance, their apparent brightnesses will be proportional to their surfaces.

Let us take as an example Sirius and our sun, of which the "magnitudes" are -1.6 and -26.7 . The difference is approximately 25 magnitudes, corresponding to a ratio of apparent brightness

$$(\text{Sun})/(\text{Sirius}) = 10,000,000,000.$$

If we admit for the moment that the two stars have the same brightness per unit surface, we must then also admit that their apparent surfaces are in the same ratio, 10,000,000,000. The apparent diameters are in the ratio of the square root of this, or 100,000. Since the diameter of the sun is $1,800''$, that of Sirius is $0''.018$.

Let us consider another example: Betelgeuse is 2.5 magnitudes fainter than Sirius. Its brightness is therefore 10 times smaller and its diameter the square root of 10 times smaller or $0''.006$.

These diameters correspond to their true diameters only provided that the intrinsic brightnesses of these stars and of the sun are all the same. A priori, nothing could be less certain. However, these values, taken in their proper significance, are precise. They are the diameters which we must assume for fictitious stars of the same surface brightness as the sun, in order that if substituted for the real ones, their brightnesses would be of the same magnitude as the real ones. E. C. Pickering has designated such values as *equivalent diameters*.

Having reached this far, to go farther we need to know more of the surface brightnesses of the stars. This becomes possible through the advance of spectroscopy and the physics of radiation. From the laws of radiation we glean two essential properties of radiating bodies:

First, the energy of radiation per unit surface increases with the temperature; it is proportional to the fourth power of the absolute temperature when the body is a "black body." (Law of Stefan.)

Second, the spectrum composition of the emitted light also varies with the temperature; in the spectrum of a black body, the wavelength corresponding to the maximum intensity of energy is inversely proportional to the absolute temperature. (Law of Wien.) In simpler words, as a body becomes hotter, its emitted light changes from red to white to blue.

We therefore have reason to think the yellow and red stars are colder than the white or blue ones. Consequently the former radiate much less light than the latter for equal surfaces. The equivalent diameters cannot in general be equal to the true diameters. The stars of superior intrinsic brightness to the sun are smaller than our

calculations indicate, and inversely. That our determinations may be more precise, it will be next necessary to summarize briefly the principal basic facts of stellar spectra.

SPECTRUM CLASSIFICATIONS AND STELLAR TEMPERATURES.

The classification now universally adopted is that of Harvard. We will pass in review the principal classes. The classes have been arranged in the order of decreasing⁴ temperatures. We can assure ourselves of this in verifying that, from one class to the next, the maximum intensity retreats toward the red (at the right) and that the blue end progressively disappears.

The first spectrum shows the type of class B, or *helium stars*.⁵ Their temperatures are very high. Their light is very white or blue. Their absorption spectrum contains helium lines. Hydrogen lines present are usually dark but at times bright. The metallic lines are absent.

We pass next to the classes A and F characterized by the intensity of the *absorption spectrum of hydrogen*. The lines of this element belonging to the Balmer series are very noticeable (types A and F and intermediate type F₅) huddling together in the violet. The metallic lines make their debut in class A, but they do not become very abundant until in the spectra of type F. The latter class is especially noteworthy for the extraordinary development of the H and K violet lines of calcium which are faint in the preceding classes.

The temperature becomes still lower in passing to class G where our sun belongs. The *metallic lines* become definitely preponderant; those of hydrogen are yet more intense (C and F Fraunhofer lines) but less so than those of calcium. The Balmer series ceases to give the spectrum its characteristic aspect. The *absorption lines of helium* have disappeared. We know that they cannot be observed in the sun's ordinary spectrum. Helium was discovered in the sun because of its bright line spectrum in the chromosphere.

The stars of class K are distinctly yellow or reddish. The metallic lines are so numerous and strong that the continuous spectrum is reduced to a few bright rays upon a sombre background. The scale of the figure is perhaps not large enough to show this structure but what can be surely seen is the weakening of the blue part of the spectrum. This indicates a comparatively low temperature.

⁴ The letters designating the classes are not now arranged in alphabetical order. It would take too long to recount the history and evolution of the Harvard classification. Experience has arranged the classes in the order indicated.

⁵ We are leaving out of consideration the planetary nebulae which make up the class P, the nebular stars, placed in class Q, and also the so-called Wolf-Rayet stars constituting class O. The spectra of the last class contain a number of bright lines upon a feeble ground. They seem related to novae or "new stars" and are apparently yet hotter than the stars of type B. The study of them is not so far advanced as for the stars described in the body of the text.

The same thing is yet more apparent in the case of type M which includes a part of the *red stars*. The appearance of a banded spectrum belonging to *titanium oxide* confirms a considerable lowering of temperature in the case of class M. The temperature of these stars, indeed, cannot exceed that of the electric arc. At higher temperatures, these bands characteristic of composite molecules, vanish because of atomic separation of the molecules.

We come finally to the stars of class N which are especially characterized by bands due to carbon. This group contains only very red and at the same time faint stars.

The essential features of the Harvard classification are given in the following table. It also contains the probable values of the effective temperatures of each spectrum class as indicated from a consideration of all the values published.

Class.	Characteristic spectrum.	Temperatures.
B.....	Helium lines.....	15,000
A.....	Hydrogen lines.....	10,000
F.....	Hydrogen and metallic lines.....	7,000
G.....	Metallic lines.....	5,000-6,000
K.....	Metallic and broad lines.....	4,000-5,000
M.....	Banded spectra.....	3,000
N.....	Carbon bands.....	2,700

If we now assume Stéfan's law applicable, at least as a first approximation, we can, based upon these temperatures, make calculations of the relative amounts of energy emitted per unit surface by the various stars. For example, let us calculate the diameter of Sirius. Taking its temperature as $8,500^{\circ}$ and that of the Sun as $6,000^{\circ}$, we obtain from the fourth powers of these temperatures a ratio of about 4 to 1. Therefore, for equal surfaces, Sirius radiates four times more energy than does the Sun. Accordingly we have assigned to it a surface four times too great. We should divide the equivalent diameter by 2 in order to obtain a more probable value for its true diameter. Thus we finally get $0''.009$.

A number of writers have applied the preceding considerations to the determination of stellar diameters. They have utilized the best possible observational data, searching to reduce to a minimum the share taken by hypotheses.

The angular diameters calculated for Betelgeuse by Eddington, Nordmann, and Russell are respectively $0''.051$, $0''.059$, and $0''.031$. We must fix our ideas only on the "orders" of magnitude and not regard these as precise determinations. With this reservation, the accordance is satisfactory. It will appear even more so when we see

that the diameter measured by Michelson is exactly the mean of the values just given.

THE DENSITY OF THE STARS.

If we know the angular diameter, we must then have the parallax in order to calculate the linear diameter and compare it, say with that of the sun. The calculation is simple enough, for the quotient of the angular diameter by the parallax gives the real stellar diameter expressed in astronomical units, that is, in terms of the distance from the earth to the sun. This may then be expressed in solar diameters. The following results are based on a table of Russell's data:

Star.	Linear diameter compared to the sun.	Star	Linear diameter compared to the sun.
Betelgeuse.....	220	Sirius.....	1 9
Antares.....	110	Vega.....	3.6
Aldebaran.....	44	Procyon.....	1.8
Capella.....	26	Altair.....	1 4
β Andromedae.....	40		

The contrast between the two sections of this table is striking. To the right we see stars whose diameters average scarcely greater than the sun's; to the left they average 100 times greater. It is not unlikely that there are stars three or four times smaller than the sun. We arrive therefore at the fundamental conclusion that the diameters of the stars vary through a range of 1 to 1,000. The extreme volumes are therefore as 1 to 1,000,000,000.

The capital interest of this result appears when we consider a parallel comparison of the masses. We find that the stars with such different volumes have almost the same masses. We can actually calculate the masses only in the case of binary stars whose orbital elements and radial velocities are known. These are unfortunately small in number, perhaps 150. Their masses lie within the range 0.17 and 30, the mass of the sun being taken as unity. Can we draw general conclusions applicable to all the stars? We do not know. The discovery of an optical method for the determination of the masses of single stars might help us. The principle of relativity has perhaps opened the way to such a discovery, but while waiting on that we are reduced to theoretical methods. The most natural is to admit that there is no systematic difference between single stars and the components of double ones. We will suppose then, what appears otherwise probable, that the masses of both are of the same order of magnitude.

As we have just seen, the masses found in the case of double systems fall within rather narrow limits, and the ratio between the extreme values is not above 1.000. We are thus forced to conclude that the amount of condensation attained by the stars varies very much from one to another for the range of masses stretches from 1 to 1,000 whereas that of the volumes is from 1 to 1,000,000,000. We must conclude that certain stars have a density a million times smaller than others. A specific comparison will emphasize the difference: platinum is only 250,000 times as dense as hydrogen under normal circumstances.

We can foresee the importance of such a result for cosmogony and the theory of evolution. Despite its acknowledged dependence to some extent on hypotheses it conforms to all the known facts as well as to the theoretical researches of Eddington.

The immense diversity of stellar densities seems to be thus well established.

DWARF AND GIANT STARS.

So far we have been forced, in order to estimate stellar diameters, to get first the angular diameter and then to correct for the distance of the star from the earth. We can perform the operation in a single step by starting from the *absolute magnitudes* since these are referred to a standard distance.

A list of 1,646 stars whose absolute magnitudes were directly obtained by the remarkable method of Adams has just been published. This carries to nearly 2,500 the number of stars for which we have this datum.

Interesting consequences follow from a statistical study of these stars. In order legitimately to infer diameters from these results we must first assort the stars into classes. It is only with stars of the same spectrum type that we may infer equality of surface brightness.

Figure 1 shows graphically the results. The abscissae refer to absolute magnitudes, the ordinates, the numbers of stars of the different spectrum classes. A capital result at once catches the eye. It is the separation of the stars in each of the advanced classes into two perfectly distinct groups. While the curves for classes B, A, and F show only one summit, corresponding to the most frequent magnitude, the other curves each have two maxima. The first corresponds to giant stars, the second to dwarfs. Thus we here find verified with an unexpected definiteness the existence of stars of very different volumes. Further there is not a continuous variation in the number of stars as we pass from the giants of one class to the dwarfs of the same class.

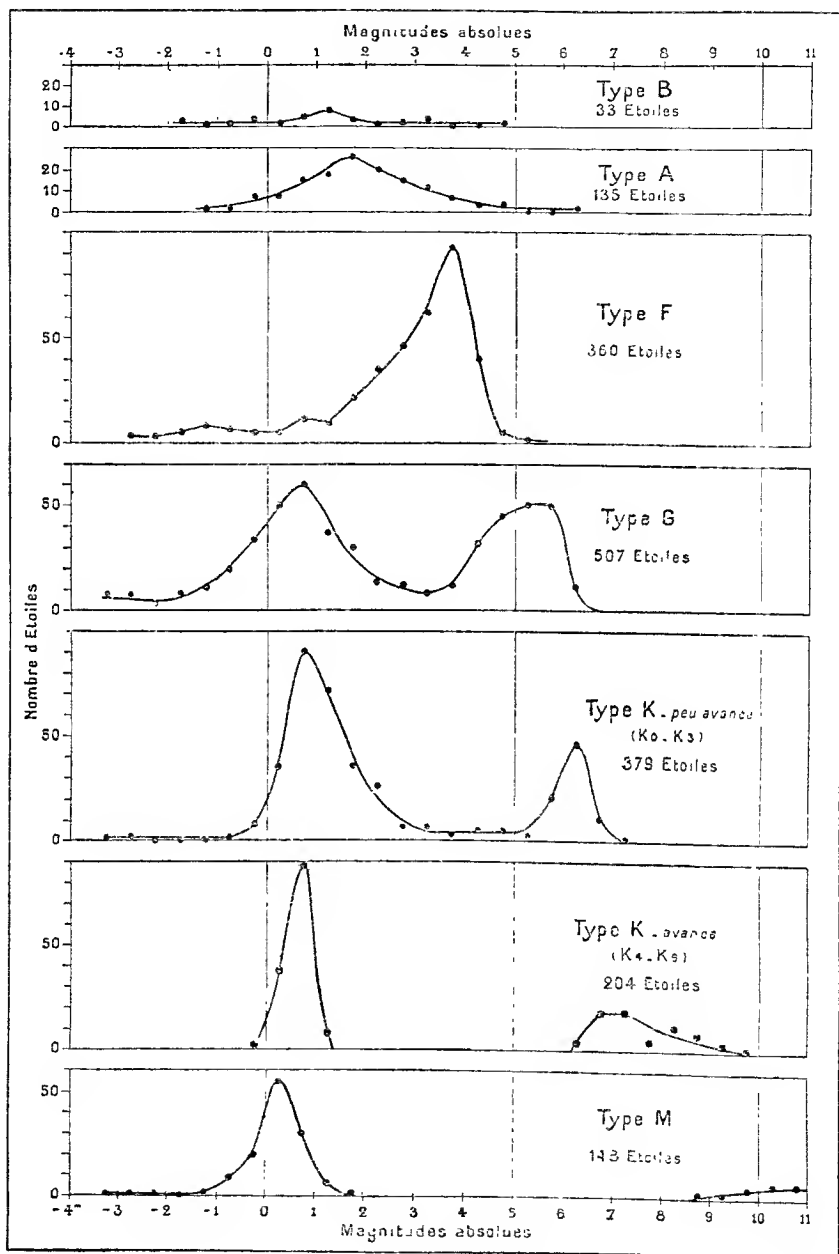


FIG. 1.—Curves showing the distribution of absolute magnitudes among the different spectrum classes.

The abscissae show the absolute magnitudes, reduced to a distance of 10 parsecs (34 light years); the ordinates give the corresponding number of stars, each point corresponding to an interval of half a magnitude.

The following data shows the magnitudes, corresponding to the maxima of the curves.

Class.	Magni- tude.	Class.	Magnitude.	
			Giants.	Dwarfs.
B.....	1.0	G.....	0.5	5.5
A.....	1.5	K ₀ -K ₃	1.0	6.0
F.....	3.5	K ₄ -K ₉	0.5	7.0
		M.....	0.0	10.0

The mean frequency of the giant stars of class G and that of the dwarfs of the same type are separated by an interval of five magnitudes. Calculation easily shows that the former are therefore 1,000 times less dense. In class M the ratio of volumes amounts to 1,000,000. Greater values naturally are obtained by comparing the greatest giant stars with the smallest dwarfs. Our conclusions of the preceding section are strikingly confirmed.

Let us consider a moment the cosmogony developed by Russell. He was the first to call attention to this separation of the stars into dwarfs and giants. According to him, giant stars are young stars. As they age they contract and grow warmer. The dwarfs are stars already condensed and in the process of cooling off and becoming dark.

A star thus commences life as a giant, relatively cold. Gravitation leads to its contraction, the energy due to the compression raising the star's temperature. Thus in measure as its radiating surface decreases, its intrinsic brightness increases in such a manner that its apparent brightness remains practically constant. As another result of the increasing temperature the spectrum type alters and the star mounts from one class to another in the order, M, K, G, F, etc.*

The density of a star, however, tends to a limit and the contraction becomes slower and slower. When the giant star enters the hot classes A and B, its diameter will be scarcely greater than the sun's. The converted gravitational energy then ceases to compensate for the radiation losses. The temperature passes a maximum and commences to decrease. The star becomes a dwarf whose diameter from then on decreases almost insensibly and retrogrades down the series of spectrum classes in the order, B, A,-----K, M. During their evolution stars pass twice through each spectrum class, first as a giant and finally as a dwarf. The second time its surface brightness decreases rapidly. The star grows fainter and fainter and redder as it passes to its final extinction. Thus Betelgeuse is a young star. Sirius has attained a ripe age, and the sun is in its decline.

*It was thought evident before the data just given was obtained that stars like Betelgeuse and Aldebaran were in the process of cooling off and extinction. We see now how risky such *a priori* conclusions are.

What has been stated shows how, without direct measures, the astrophysicists have succeeded in obtaining the dimensions of stars, and also that they have brought to light a number of quite unexpected facts. Despite the likelihood of the hypotheses developed on the way, a direct verification becomes increasingly desirable. Back in 1868 Fizeau proposed a method for the direct measurement of stellar diameters. Stéphan approached the problem at Marseilles with a telescope of 0.80 meters, but only showed the extreme minuteness of the stellar disks. He proved that in order to measure them a much larger instrument would be necessary. The task came to Prof. A. A. Michelson of developing the exact theory and of making its first successful application to the stars. We will in the succeeding sections outline his methods saying here only that his measurements confirm in a remarkable manner the most hazardous deductions of the astrophysicist.

THE INTERFERENTIAL METHOD.

We have said that in 1868 Fizeau proposed the application of the interference of light to the measurement of star diameters. The method rests upon the following principle. When we try to produce interference by Young's apertures, Fresnel's mirrors, or a biprism, we find that the apparent diameter of the luminous source must be very small if the fringes are to be pure.⁷ If we employ as the source of light a hole of variable diameter, lit from behind, we find in fact that the sharpness of the fringes decreases as the diameter of the hole increases. For a certain value of the diameter the fringes become completely invisible. The finer and more marked the fringes, the smaller must be the source. There is a proportionality between the separation of the fringes and the limiting diameter of the source. Michelson, to whom we owe the complete theory of the phenomenon, showed in 1891 that the fringes of Young and of Fresnel become invisible when the angular diameter of the source is a little greater than the interval δ which separates one fringe from the next. He found indeed that

$$\omega = 1.22 \delta$$

Why do the fringes disappear in the case of an extended source? It is easy to see why. Each separate point of the source will give, if it alone exists, a system of pure fringes. But the systems corresponding to the different points of the source will trespass upon each other's ground and mutually blend together. The complete disappearance comes when the superposition of the various

⁷ The reader may observe an example of the "interference fringes" of which we are about to speak, if he will admit sunlight through an almost vanishingly narrow slit upon white paper within a darkened room.

systems produces a uniform intensity. The application of these considerations to the angular diameters is direct. If we have a star for our source whose angular diameter we may call ω , and if we can cause the fringes to vary and disappear at will, we can find by trial the value of δ for which they first disappear. From the formula just given we at once obtain ω .

THE APPARATUS OF STÉPHAN.

The method suggested by Fizeau was put into practice by Stéphan at the Marseilles Observatory in 1873. The telescope objective of 80 centimeters aperture was covered with an opaque screen having two apertures symmetrically placed with regard to the center (fig. 2).

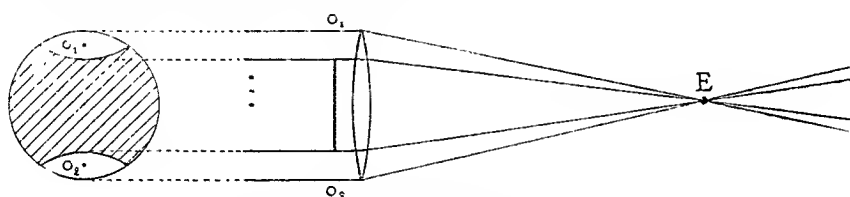


FIG. 2.—Plan of Stéphan's apparatus (1873).

A screen, shown in plan at the left of the figure, limits the portion of the objective utilized to two openings, O_1 and O_2 . The fringes are observed with a powerful eye piece at the image of the star E.

Under such conditions the objective utilizes only two narrow pencils of rays coming from the star. These converge at the focal plane E to the image of the star. If the image is examined with a powerful eye-piece the usual diffraction spot will be seen furrowed now with dark equidistant bands perpendicular to the line O_1O_2 which joins the centers of the apertures. These are the interference fringes, exactly analogous to those which form on the retina in Young's famous experiment and of which the angular separation is

$\delta = \lambda/D$ where λ is the wave length of light and D the distance O_1O_2 .

In the experiments of Stéphan, the apparatus could not distinguish angular diameters less than $1/3$ of a second of arc. Now all the stars observed by Stéphan in 1873 and 1874 gave *very clear-cut fringes*. None of them could therefore equal $0''.2$ in diameter. Probably the largest were far beneath this value. We know to-day that they do not exceed $0''.05$.

The interferometer method was later independently applied by Michelson and Hamy to the measurement of the satellites of Jupiter. As this meant working with diameters of $0''.5$ to $1''$ a telescope of 30 centimeters aperture was amply sufficient, and positive results were obtained.

Apart from this encouraging result, the measurement of stellar disks seemed more and more difficult to undertake. It is easily calculated that an aperture of 2.50 meters (nearly 7 feet) is large enough only for stars whose diameter exceeds $0''.05$. There now exists at Mount Wilson a telescope of that aperture, the Hooker telescope. Furnished with an apparatus similar to that of Stéphan, it showed fringes no matter what star was examined. Stars of diameter greater than $0''.05$ therefore do not seem to exist.

Must we therefore renounce the measurement of stellar diameters or rather await the production of an objective of 5 to 10 meters aperture? An artifice, conceived and carried out with incomparable ability by Prof. A. A. Michelson, of the University of Chicago, rescued astronomy from this perplexing dilemma.

THE STELLAR INTERFEROMETER OF MICHELSON.

The advantages and uniqueness of the interferential method lie in that we may measure stars whose diameters are smaller than the resolving power of the telescope.

In fact the problem consists in causing to interfere two bundles of rays of which the initial linear separation D is considerable. But it is not necessary to employ a telescope objective of diameter D . This principle guided Michelson. Therefore the interferometer which he constructed gives a most simple solution to the problem. Four plane mirrors (fig. 3) gather two bundles of rays and reflect

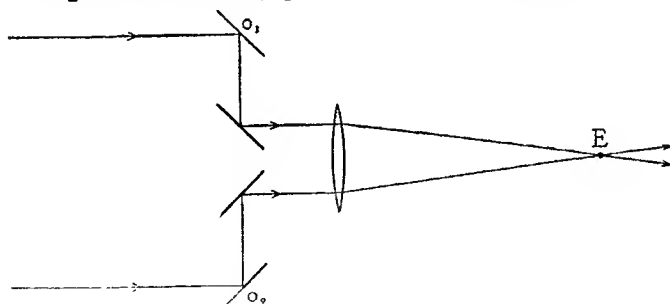


FIG. 3.—Plan of Michelson's interferometer.

The arrangement proposed in 1891, and used at Mount Wilson in 1920, allowed the interference of two pencils of rays, separated by several meters, while using an objective of ordinary dimensions.

them parallel but nearer together into the objective of a small telescope. It is no longer necessary to have a giant telescope but in its place plane mirrors and an ordinary objective carried by a rigid mounting. The difficulties are now purely mechanical. The problem becomes approachable through the resources of modern mechanical



THE INTERFEROMETER OF MICHELSON MOUNTED AT THE FRONT OF THE 2.50 METER TELESCOPE OF MOUNT WILSON; SEE ALSO THE EXPLANATORY FIGURES 234 AND 235.

technique. Nevertheless many physicists might have hesitated, despite this simplification, at the idea of causing two bundles of rays to interfere which at their start were situated 5 or 10 meters apart. For approaching this startling feat, the audacity of the American physicist, his profound knowledge of optics and long experience with the most delicate apparatus was necessary.

The first interferometer, constructed in 1920, had the two receiving mirrors 6 meters apart. They were mounted upon the Hooker telescope (fig. 4), not because of its optical power, which was not

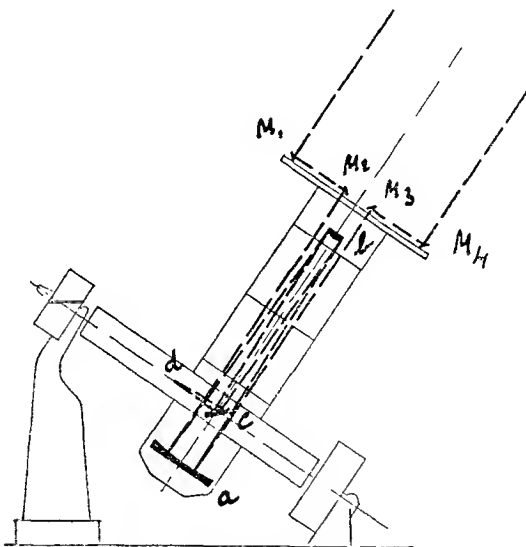


FIG. 4.—The 2.50 meter telescope provided with the interferometer.

The light, reflected by the mirrors, M_1 , M_2 , M_3 , and M_4 of the interferometer upon the great parabolic mirror a , is then reflected to the hyperbolic mirror b (the telescope is mounted as a Cassegranian). A plane mirror c , inclined at 45° , then sends the light to the eye-piece d situated at the side of the tube. It is close to this ocular that the compensating glasses are placed.

necessary, as we have just seen, but because of the advantages which accrued from its massive and rigid equatorial mounting, which admitted the extra load without accompanying trouble. Another interferometer of 16 meters, now actually under construction, will, on the contrary, be an independently mounted instrument.

We will give some details of the 6-meter instrument. The mirrors, 15 centimeters in diameter, are carried by a trussed girder. The two central mirrors are mounted 1.14 meters from each other. The other two can be reciprocally displaced. In order to accomplish this their supports are mounted on slide rests moved by two screws.

The simultaneous motion of the screws is accomplished by a small electric motor worked from a distance by the observer (fig. 5).

The method of observing consists in separating and approaching the first two mirrors and observing the sharpness of the fringes. When they become invisible the distance D of the mirrors M_1M_4 is recorded. The theory is not wholly identical with that of the experi-

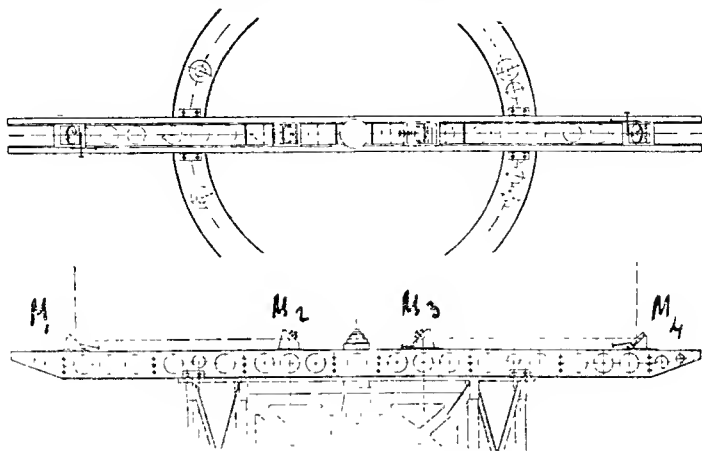


FIG. 5.—Detailed plan of the interferometer. M_1 , M_2 , M_3 , M_4 , plane mirrors, mounted on moving carriages.

ment of Stéphan, so that his formula is not applicable. However, the formula for the angular diameter is still

$$\omega = 1.22 \lambda / D.$$

A readjustment is necessary after each displacement of the mirrors. For easing the labor of this, Michelson has devised various cunning contrivances without which the observations would have been excessively laborious if not impossible.

THE DIAMETER OF BETELGEUSE.

The decisive observation was made by Pease and Anderson on the 15th of December, 1920. The definition was fine and the images were observed without difficulty. The stars β Persei, γ Orionis, and α Canis Majoris gave fringes with D equalling 306 centimeters. But when the apparatus was trained upon Betelgeuse without changing the distance of the mirrors the fringes could not be seen. At a distance of 250 centimeters they appeared, although hazy. It was allowable then to call the value of D equal to 3 meters with an accuracy of about 10 per cent. We thence have

$$\omega = 0''.047.$$

A restriction is, however, necessary. The theory postulates that the star disk is uniformly bright. It is more probably progressively

darker from the center outwards just as is the solar disk. Admitting that Betelgeuse has the same distribution of brightness as the sun, the value obtained from the formula must be increased by an amount which can not be exactly computed but which is about 15 per cent.

Michelson even proposes to determine the law of distribution of brightness upon the disk of Betelgeuse by a thorough study of the change in the sharpness of the fringes in approaching the minimum.

Admitting for the present the value $0''.047$, let us get the linear diameter of the star. The best parallax from measures by several observers is $0''.017$. The diameter of Betelgeuse is therefore

$$\begin{aligned} 0.047/0.017 &= 2.7 \text{ astronomical units} \\ &= 300 \text{ solar diameters.} \end{aligned}$$

The equator of this giant star would thus contain the earth's orbit (two astronomical units in diameter) and nearly that of Mars (3.4 astronomical units.) That is in full accord with the earlier estimates.

The measurement of Arcturus made by Pease February 12, 1921, has also checked with the theoretical value. For this star it was necessary to use the total available length of the interferometer, 6 meters. This gives for Arcturus a diameter of $0''.024$. The diameter predicted by Russell was $0''.019$. The parallax of the star is $0''.095$, according to van Maanen and Russell. Its diameter in linear measure is, therefore, 28 times that of the sun.

Finally, more recent observations have led to the value $0''.040$ for the angular diameter of Antares. The most probable parallax is $0''.023$. Whence we deduce a diameter for Antares 200 times larger than the sun's. Again the order of magnitude predicted is confirmed.

ATOMIC WEIGHTS AND ISOTOPES.¹

By F. W. ASTON, M. A., D. Sc., F. R. S.,
Fellow of Trinity College, Cambridge.

That matter is discontinuous and consists of discrete particles is now an accepted fact, but it is by no means obvious to the senses.

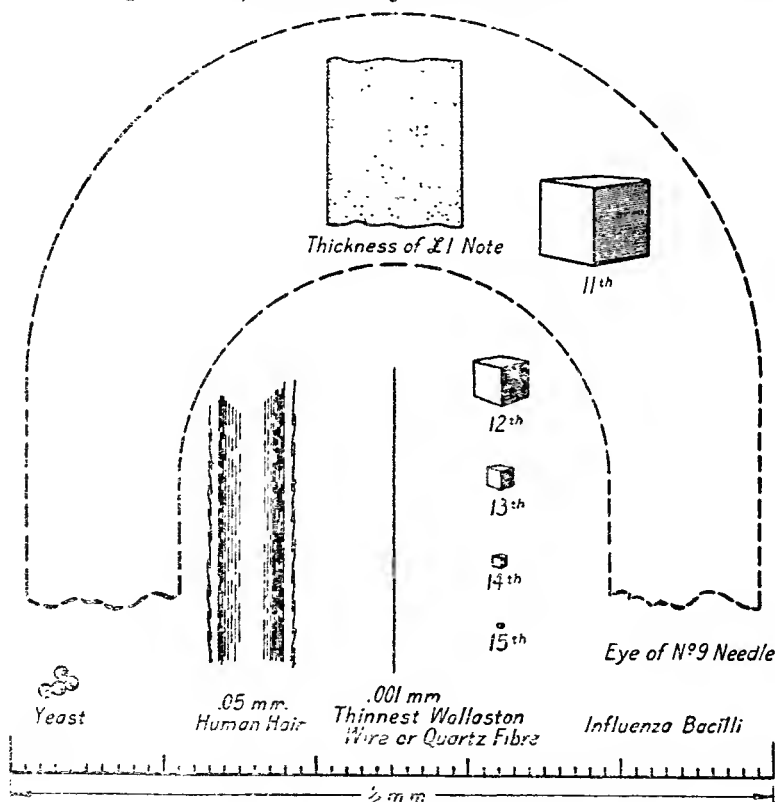


FIG. 1.—Cubes 11 to 15 compared with familiar objects to scale.

The surfaces of clean liquids, even under the most powerful microscope, appear perfectly smooth, coherent, and continuous. The

¹ Abstract of a summary of a series of lectures given before The Franklin Institute, March 6–10, 1922. Reprinted by permission from the Journal of the Franklin Institute, May, 1922.

merest trace of a soluble dye will color millions of times its volume of water. It is not surprising therefore that in the past there have arisen schools who believed that matter was quite continuous and infinitely divisible.

The upholders of this view said that if you took a piece of material, lead, for instance, and went on cutting it into smaller and smaller fragments with a sufficiently sharp knife, you could go on indefinitely. The opposing school argued that at some stage in the opera-

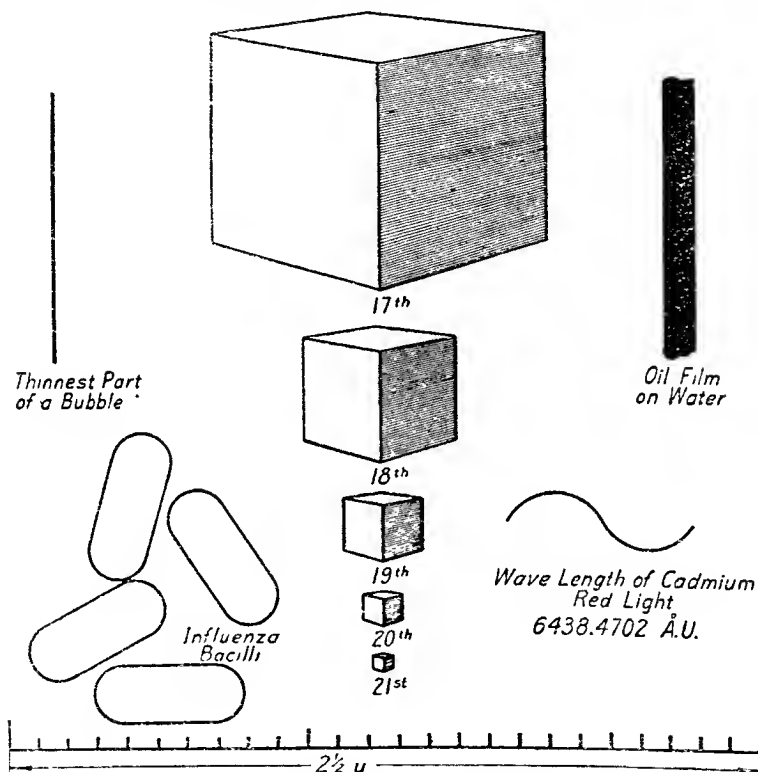


FIG. 2.—Cubes 17 to 21 compared with minute objects to scale.

tions either the act of section would become impossible, or the result would be lead no longer. Bacon, Descartes, Gassendi, Boyle, and Hooke were all partial to the latter theory, and Newton in 1675 tried to explain Boyle's Law on the assumption that gases were made up of mutually repulsive particles.

The accuracy of modern knowledge is such that we can carry out, indirectly at least, the experiment suggested by the old philosophers right up to the stage when the second school is proved correct, and the ultimate atom of lead reached. For convenience, we will start with a standard decimeter cube of lead weighing 11.37 kilograms,

and the operation of section will consist of three cuts at right angles to each other, dividing the original cube into eight similar bodies each of half the linear dimensions and one-eighth the weight. Thus the first cube will have 5 cm. sides and weigh 1.42 kilograms, the second will weigh 178 grs., the fourth 2.78 grs., and so on. Diminution in the series is very rapid and the result of the ninth operation is a quantity of lead just weighable on the ordinary chemical balance. The results of further operations are compared with suitable objects and a scale of length in Figures 1, 2, and 3. The last operation possible, without breaking up the lead atom, is the twenty-eighth. The twenty-sixth cube is illustrated in Figure 3. It contains 64 atoms, whose size, distance apart, and general arrangement can be represented with considerable accuracy, thanks to the exact knowledge derived from research on X rays and specific heats. On the same scale are represented the largest atom, caesium, and the smallest atom, carbon, together with molecules of oxygen and nitrogen, at their average distance apart in the air, and the helical arrangement of silicon and oxygen atoms in quartz crystals discovered by X-ray analysis. The following table shows at what stages certain analytical methods break down. The great superiority of the microscope is a noteworthy point.

Cube.	Side in cms.	Mass in grms.	Limiting analytical method.
9	.0195	3.5×10^{-6}	Ordinary Chemical Balance.
14	6.1×10^{-4}	2.58×10^{-9}	Quartz Micro-balance.
15	3.05×10^{-4}	3.22×10^{-10}	Spectrum Analysis (Na lines).
18	3.8×10^{-5}	6.25×10^{-13}	Ordinary Microscope.
24	6.0×10^{-7}	2.38×10^{-18}	Ultra Microscope.
28	3.7×10^{-8}	5.15×10^{-22}	
Atom.	3.0×10^{-8}	3.44×10^{-22}	Radioactivity.

Just as any vivid notion of the size of the cubes passes out of our power at about the twelfth—the limiting size of a dark object visible to the unaided eye—so when one considers the figures expressing the number of atoms in any ordinary mass of material, the mind is staggered by their immensity. Thus, if we slice the original decimeter cube into square plates one atom thick the area of these plates will total one and one-quarter square miles. If we cut these plates into strings of atoms spaced apart as they are in the solid, these decimeter strings put end to end will reach 6.3 million million miles, the distance light will travel in a year, a quarter of the distance to the nearest fixed star. If the atoms are spaced but one millimeter apart the string will be three and a half million times longer yet, spanning the whole universe.

Again, if an ordinary evacuated electric light bulb were pierced with an aperture such that one million molecules of the air entered per second, the pressure in the bulb would not rise to that of the

air outside for a hundred million years. Perhaps the most striking illustration is as follows: Take a tumbler of water and—supposing it possible—label all the molecules in it. Throw the water into the sea, or indeed, anywhere you please, and after a period of time so great that all the water on the earth—in sea, lakes, rivers, and clouds—has had time to become *perfectly mixed*, fill your tumbler again at the nearest tap. How many of the labeled molecules are to be expected in it? The answer is, roughly, 2,000; for although the

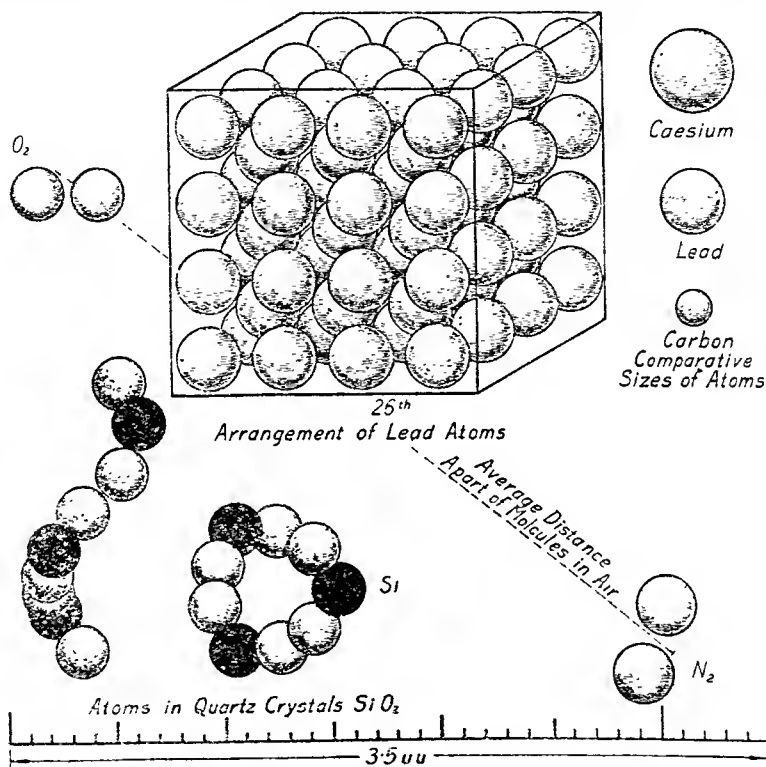


FIG. 3.—Cube 26 showing atoms with scale of reference.

number of tumblers full of water on the earth is 5 by 10^{21} , the number of molecules of water in a single tumbler is 10^{25} .

From the above statements it would, at first sight, appear absurd to hope to obtain effects from single atoms, yet this can now be done in several ways, and, indeed, it is largely due to the results of such experiments that the figures can be stated with so much confidence. Detection of an individual is only feasible in the case of an atom moving with an enormous velocity when, although its mass is so minute, its energy is quite appreciable. The charged helium atom shot out by radioactive substances in the form of an alpha ray possesses so much energy that the splash of light caused by its impact

against a fluorescent screen can be visibly detected, the ionization caused by its passage through a suitable gas can be measured on a sensitive electrometer and, in the beautiful experiments of C. T. R. Wilson, its path in air can be both seen and photographed by means of the condensation of water drops upon the atomic wreckage it leaves behind it.

In the first complete Atomic Theory put forward by Dalton in 1803 one of the postulates states that: "Atoms of the same element are similar to one another and equal in weight." Of course, if we take this as a definition of the word "Element" it becomes a truism, but, on the other hand, what Dalton probably meant by an element, and what we understand by the word to-day, is a substance such as hydrogen, oxygen, chlorine, or lead, which has unique chemical properties and can not be resolved into more elementary constituents by any known chemical process. For many of the well-known elements Dalton's postulate still appears to be strictly true, but for others, probably the majority, it needs some modification.

The idea that atoms of the same element are all identical in weight could not be challenged by ordinary chemical methods, for the atoms are by definition chemically identical and numerical ratios were only to be obtained in such methods by the use of quantities of the element containing countless myriads of atoms. At the same time it is rather surprising, when we consider the complete absence of positive evidence in its support, that no theoretical doubts were publicly expressed until late in the nineteenth century, first by Schutzenberger and then by Crookes, and that these doubts have been regarded, even up to the last few years, as speculative in the highest degree. In order to dismiss the idea that the atoms of such a familiar element as chlorine might not all be of the same weight, one had only to mention diffusion experiments and the constancy of chemical equivalents. It is only within the last few years that the lamentable weakness of such arguments has been exposed and it has been realized that the experimental separation of atoms differing from each other by as much as 10 per cent in weight, is really an excessively difficult operation.

There are two ways by which the identity of the weights of the atoms forming an element can be tested. The one is by the direct comparison of the weights of individual atoms, the other is by obtaining samples of the element from different sources or by different processes, which, although perfectly pure, do not give the same chemical atomic weight. It was by the second and less direct of these methods that it was first shown that substances could exist which, though chemically identical, had different atomic weights.

In 1906 Boltwood,² at Yale, discovered a new element in the radio-

² Boltwood: Amer. J. Sci., 22, 537, 1906; 24, 370, 1907.

active group which he called ionium, and described as having chemical properties similar to those of thorium. So much was this the case that if, by accident, salts of these two elements were mixed, he found it impossible to separate them again by any of the chemical processes. This chemical identity was confirmed in the most convincing manner by the later work of Marckwald, Keetman³ and Welsbach,⁴ although the two elements certainly had different radioactive properties and it was extremely probable that they had different atomic weights. More identities of a similar nature among the radioactive elements were discovered by Soddy,⁵ Hahn,⁶ and others, and the situation in 1910 will be found admirably summed up by Soddy in his report to the Chemical Society for that year.⁷ In 1912, Russel and Rossi⁸ showed that the spectra of ionium and thorium were indistinguishable and Rutherford's theory of the "Nucleus Atom" supplied a possible explanation. The association of the chemical and spectroscopic properties of an element with something more fundamental than its atomic weight, namely, the charge on the nuclei of its atoms or its "Atomic Number," was proved by the epoch-making work of Moseley in 1913.⁹ This idea gave a simple and entirely satisfactory meaning to the chemical laws of the radioactive disintegrations discovered a little earlier and predicted that among the numerous products of these disintegrations there must of necessity be some having identical chemical properties but different atomic weights.

To the latter the name "Isotopes" was applied by Soddy in the following words: "The same algebraic sum of the positive and negative charges in the nucleus when the arithmetical sum is different gives what I call 'isotopes' or 'isotopic elements,' because they occupy the same place in the periodic table. They are chemically identical, and save only as regards the relatively few physical properties which depend upon atomic mass directly, physically identical also."

The theory of isotopes received its most triumphant vindication, as far as it concerned the products of radioactivity, from the results of work on the atomic weight of lead. Study of the radioactive disintegrations shows that the final product of every series is lead. If we take the main chain of the uranium-radium transformation, this lead must have an atomic weight 206, for it has lost 5 alpha particles—each of weight 4—since it was radium, and the atomic weight of radium is 226. On the other hand, if we take the main thorium

³ Keetman: *Jahr. Radioaktivität*, 6, 269, 1909.

⁴ A. von Welsbach: *Wien. Ber.*, 11a, 119, 1011, 1910.

⁵ Soddy: *Trans. Chem. Soc.*, 99, 72, 1911.

⁶ Hahn and Meitner: *Physikal. Zeitsch.*, 11, 493, 1910.

⁷ *Chem. Soc. Ann. Rep.*, 285, 1910.

⁸ Russel and Rossi: *Proc. Roy. Soc.*, 77A, 478, 1912.

⁹ Moseley: *Phil. Mag.*, 26, 1031, 1913.

chain, the lead end product must be 6 alpha particles lighter than thorium (232.15), and so should have an atomic weight about 208.

Now, ordinary lead from nonradioactive sources has an atomic weight 207.20, so Soddy¹⁰ suggested in 1913 that the lead derived from minerals containing uranium but no thorium might have a smaller atomic weight than ordinary lead, and, on the other hand, the atomic weight of lead from minerals containing thorium but no uranium might be greater.

The first experiments were made by Soddy and Hyman¹¹ with a very small quantity of lead from Ceylon thorite. This gave a perceptibly higher atomic weight than ordinary lead. Later a large quantity of the same mineral was available. The lead from this when carefully purified gave a density of 0.26 per cent higher than that of common lead. On the assumption that the atomic volumes of isotopes are equal, this figure corresponds to an atomic weight of 207.74. A chemical atomic weight determination gave 207.694. A sample of the same lead was sent to Vienna, where Professor Honigschmid, a well-known expert in such matters, obtained from it a value 207.77 as a mean of eight determinations. These figures not only showed that thorium lead had a higher atomic weight than ordinary lead but also that their atomic volumes were identical, as expected from theory.¹²

At the same time as this work was in progress the leading American authority on atomic weights, T. W. Richards,¹³ of Harvard, started a series of investigations on lead derived from various radioactive minerals. The samples of lead from uranium minerals all gave results lower than ordinary lead, as was expected, and one particularly pure specimen of uranio-lead from Norwegian cleveite gave 206.08,¹⁴ a very striking agreement with theory. The following table of properties is taken from his presidential address to the American Association at Baltimore, December, 1918:

	Common lead.	Mixture Austra- lian.	Uranio- lead.	Percentage difference.	
	A	B	C	A-B	A-C
Atomic weight.....	207.19	206.34	206.08	0.42	0.54
Density.....	11.337	11.280	11.273	.42	.56
Atomic volume.....	18.277	18.278	18.281	.01	.02
Melting point (absolute).....	600.53	600.59		.01	
Solubility (of nitrate).....	37.281	37.130		.41	
Refractive index (nitrate).....	1.7815	1.7814		.01	
Thermoelectric effect.....				.00	
Spectrum wave-length.....				.00	.00

¹⁰ Ann. Rep. Chem. Soc., 269, 1913.

¹¹ Soddy and Hyman: Trans. Chem. Soc., 105, 1402, 1914.

¹² Soddy: Roy. Ins., May 18, 1917.

¹³ Richards and Lemberg: J. Amer. Chem. Soc., 36, 1329, 1914.

¹⁴ Richards and Wadsworth: J. Amer. Chem. Soc., 38, 2613, 1916.

In further confirmation Maurice Curie¹⁵ in Paris reported 206.36 for a lead from carnotite, and a still lower figure, 206.046, was obtained by Honigschmid in Vienna for a lead from the very pure crystallized pitchblende from Morogoro.¹⁶ This is the lowest atomic weight found so far. The highest, 207.9, was also determined by Honigschmid for lead from Norwegian thorite.

In the absence of the special radioactive evidence which can be used in special cases such as that of lead, the presence of isotopes among the inactive elements can only be detected by the direct measurement of the masses of individual atoms. This can be done by the analysis of positive rays.

The condition for the development of these rays is briefly ionization at low pressure in a strong electric field. Ionization, which may be due to collisions or radiation, means in its simplest case the detachment of one electron from a neutral atom. The two resulting fragments carry charges of electricity of equal quantity but of opposite sign. The negatively charged one is the electron, the atomic unit of negative electricity itself, and is the same whatever the atom ionized. It is extremely light and therefore in the strong electric field rapidly attains a high velocity and becomes a cathode ray. The remaining fragment is clearly dependent on the nature of the atom ionized. It is immensely more massive than the electron, for the mass of the lightest atom, that of hydrogen, is about 1850 times that of the electron, and so will attain a much lower velocity under the action of the electric field. However, if the field is strong and the pressure so low that it does not collide with other atoms too frequently, it will ultimately attain a high speed in a direction opposite to that of the detached electron, and become a "positive ray." The simplest form of positive ray is therefore an atom of matter carrying a positive charge and endowed, as a result of falling through a high potential, with sufficient energy to make its presence detectable. Positive rays can be formed from molecules as well as atoms, so that it will at once be seen that any measurement of their mass will give us direct information as to the masses of atoms of elements and molecules of compounds, and that this information will refer to the atoms or molecules *individually*, not, as in chemistry, to the mean of an immense aggregate. It is on this account that the accurate analysis of positive rays is of such importance.

In order to investigate and analyze them it is necessary to obtain intense beams of the rays. This can be done in several ways. The one most generally available is by the use of the discharge in gases at low pressure.

¹⁵ M. Curie: *Compt. Rend.*, 158, 1676, 1914.

¹⁶ Honigschmid: *Zeit. Elektrochem.*, 24, 163, 1918; 25, 91, 1919.

It is somewhat remarkable that notwithstanding the immense amount of research work done on the discharge at low pressure its most obvious phenomena are almost entirely without explanation; modern measurements and other data have merely destroyed the older theories without, as yet, suggesting others to replace them. In discussing positive rays it is of importance to consider the phenomena taking place immediately in front of the cathode of the discharge tube.

The comparatively dimly lit space between the cathode and the bright "negative glow" is named after its discoverer the "Crookes' Dark Space." Its length is roughly inversely proportional to the pressure of the gas in the tube. Its boundary, the edge of the negative glow, is remarkably sharp in most gases, quite amazingly so in pure oxygen. If large plane cathodes are used so that the effect of the glass walls—so far a complete mystery—does not come in, very accurate and consistent measurements of the Crookes' dark space can be made. Working with a very large "guard-ring" cathode, the writer showed in 1907¹⁷ that its length D could be expressed as

$$D = \frac{A}{P} + \frac{B}{\sqrt{i}}$$

where P is the pressure, i the current density on the surface of the cathode and A and B constants. This expression is fairly exact for ordinary gases, but only approximate for those of the helium group.¹⁸ A varies both with the nature of the gas and the metal used as cathode. With the same metal as cathode it is four to five times as big for hydrogen as for oxygen; using the same gas, it is about twice as big with a silver cathode as for one of aluminum.¹⁹ The value of the remarkable constant B , which is independent of the pressure, is also practically unchanged either by the nature of the gas, or the nature or even the shape of the cathode.

During these investigations it was also demonstrated that in the absence of the positive column, the whole of the potential V required to maintain the discharge, takes place between the cathode and the negative glow, and its relation to the current may be expressed by the equation

$$V = E + \frac{F\sqrt{i}}{P}$$

E and F being constants which depend on the nature of the gas and the metal used as cathode.

Measurements of the distribution of potential in the dark space by a method which appears free from objection²⁰ show that the field

¹⁷ Aston : Proc. Roy. Soc., 79A, 80, 1907.

¹⁸ Aston and Watson : Ibid., 86A, 168, 1912.

¹⁹ Aston : Ibid., 87A, 428, 437, 1912.

²⁰ Aston : Proc. Roy. Soc., 84A, 526, 1911.

is practically zero in the negative glow itself and increases in a linear manner as we move towards the cathode. This means that the density of the positive electrification (excess of positive over negative ions) in the dark space is constant.

No theory yet put forward can account for these numerical relations; one can, however, be certain that ionization is going on at all points throughout the dark space, and that it reaches a very high intensity in the negative glow.²¹ This ionization is probably caused for the most part by electrons liberated from the surface of the cathode (cathode rays). These, when they reach a speed sufficient to ionize by collision, liberate more free electrons which, in their turn, become ionizing agents, so that the intensity of ionization from this cause will tend to increase as we move away from the cathode.

The liberation of the original electrons from the surface of the cathode is generally regarded as due to the impact of the positive ions (positive rays) generated in the negative glow and the dark space. Even this idea, for which there is a fair amount of definite evidence, is now called in question for Ratner²² has recently described experiments proving "that the initial discharge of electricity through vacuum tubes is not brought about by the impact of positive ions against the surface of the cathode, and that positive ions impinging upon the cathode with velocities corresponding to a fall through a potential difference up to 2000 volts, are unable to liberate electrons from the surface of the cathode." It must, however, be borne in mind that the nature of the positive ions used in Ratner's experiments is not known with certainty, and that the intensity of bombardment was of an entirely different and smaller order than that usually associated with normal discharge.

During the work on the length of the dark space a very curious and interesting phenomenon was observed in hydrogen and all the gases of the helium group. This consisted of a dark space very small and very dark, immediately in front of the cathode, inside the Crookes' dark space.²³ It can only be clearly seen by looking across the face of a large plane cathode when its appearance in pure helium or neon is very striking. Its properties are completely different from those of the Crookes' dark space. Its length, which is usually less than a millimeter, is independent of the pressure and varies roughly inversely as the square root of the current density. As the field close to the cathode varies directly as the square root of the current density this suggested at once that the new dark space represented a definite constant fall of potential. There is now little

²¹ Aston : Proc. Roy. Soc., 96A, 200, 1919.

²² Ratner : Phil. Mag., 40, 795, 1920.

²³ Aston : Proc. Roy. Soc., 80A, 45, 1907.

doubt that this "Primary Dark Space," as it has been called, defines the distance through which an electron, starting from rest at the surface of the cathode, must fall before it acquires sufficient energy to ionize the gas by collision. This explanation is supported in a striking manner by the appearance of the phenomenon when the current density is greatly reduced. Under these conditions alternate dark and bright bands, equally spaced, appear in front of the cathode exactly as would be expected from the production of successive generations of ions. Further support is given by the measurements in hydrogen and helium, which indicate that the actual fall of potential across the primary dark space is twice as great for helium as for hydrogen and, on certain assumptions, is approximately equal to the ionization potential of these gases determined by other means.

In addition to cathode ray ionization the positive rays traveling towards the cathode themselves are capable of ionizing the gas, and radiation may also play an important part in the same process. The surface of the cathode will therefore be under a continuous hail of positively charged particles. Their masses may be expected to vary from that of the lightest atom to that of the heaviest molecule capable of existence in the discharge tube, and their energies from an indefinitely small value to a maximum expressed by the product of the charge they carry \times the total potential applied to the electrodes. The latter is practically the same as the fall of potential across the dark space. If the cathode be pierced, the rays pass through the aperture and form a stream heterogeneous both in mass and velocity which can be subjected to examination and analysis.²⁴

A powerful and ingenious method of generating positive rays of metallic elements has been worked out and used with great success by Dempster at Chicago.²⁵ He employs the element in the metallic state and ionizes its vapor by means of a subsidiary beam of cathode rays. The ions so produced are allowed to fall through a definite potential and being therefore of constant energy can be analyzed by the use of a magnetic field alone. By this arrangement Dempster discovered the three isotopes of magnesium²⁶ and confirmed those of lithium. A full account of this work has lately appeared.²⁷ Still more recently he has obtained results with calcium and zinc which indicate that the former consists almost entirely of an isotope 40 with probable traces of another 44, and that the latter has four isotopes—64, 66, 68, and 70. Since the vast majority of the elements

²⁴ Certain pages of the Franklin Institute article describing the method and apparatus used in Dr. Aston's so-called "mass-spectograph" investigations are here omitted, as they were given in a previous article on Dr. Aston's work in the Smithsonian Report for 1920, page 223.

²⁵ Dempster: Science, Dec. 10, 1920.

²⁶ Dempster: Science, April 15, 1921.

²⁷ Dempster: Phys. Rev., 18, 415, 1921.

not yet analyzed are metals, Dempster's method is likely to yield enormously important results in the future. A complete list of the isotopes of the nonradioactive elements so far discovered is given in the following table:

Table of elements and isotopes.

Element.	Atomic number.	Atomic weight.	Minimum number of isotopes.	Masses of isotopes in order of intensity.
H.....	1	1.008	1	1.008
He.....	2	4.00	1	4.
Li.....	3	6.94	2	7, 6.
Be.....	4	9.1	1	9.
B.....	5	10.9	2	11, 10.
C.....	6	12.00	1	12.
N.....	7	14.01	1	14
O.....	8	16.00	1	16.
F.....	9	19.00	1	19
Ne.....	10	20.20	2	20, 22 (21).
Na.....	11	23.00	1	23.
Mg.....	12	24.32	3	24, 25, 26.
Si.....	14	28.3	2	28, 29 (30).
P.....	15	31.04	1	31.
S.....	16	32.06	1	32.
Cl.....	17	35.46	2	35, 37 (39).
A.....	18	39.88	2	40, 36.
K.....	19	39.10	2	39, 41.
Ni.....	28	58.68	2	58, 60.
As.....	33	74.96	1	75.
Br.....	35	79.92	2	79, 81.
Kr.....	36	82.92	6	84, 86, 82, 83, 80, 78.
Rb.....	37	85.45	2	85, 87.
I.....	53	126.92	1	127.
X.....	54	130.2	5, (7)	129, 132, 131, 134, 136 (128, 130?)
Cs.....	55	132.91	1	133
Hf.....	80	200.6	(6)	(197-200), 202, 204.

DEMPSTER'S LATEST RESULTS.

Ca.....	20	40.07	(2)	40 (44).
Zn.....	30	65.37	(4)	(64, 66, 68, 70).

By far the most important general result of these investigations is that, with the exception of hydrogen, the weights of the atoms of all the elements measured, and therefore almost certainly of all elements, are whole numbers to the accuracy of experiment. In the majority of the figures obtained by means of the mass-spectrograph this accuracy is one part in a thousand. Of course the error expressed in fractions of a unit increases with the weight measured, but with the lighter elements the divergence from the whole number rule is extremely small.

This enables the most sweeping simplifications to be made in our ideas of mass. The original hypothesis of Prout, put forward in 1815, that all atoms were themselves built of atoms of protyle, a hypothetical element which he tried to identify with hydrogen, is now reëstablished, with the modification that the primordial atoms are of two kinds: Protons and electrons, the atoms of positive and negative electricity.

The Rutherford atom, whether we take Bohr's or Langmuir's development of it, consists essentially of a positively charged central nucleus around which are set planetary electrons at distances great compared with the dimensions of the nucleus itself.

As has been stated, the chemical properties of an element depend solely on its atomic number, which is the charge on its nucleus expressed in terms of the unit charge, e . A neutral atom of an element of atomic number N has a nucleus consisting of $K+N$ protons and K electrons, and around this nucleus are set N electrons. The weight of an electron on the scale we are using is 0.0005, so that it may be neglected. The weight of this atom will therefore be $K+N$, so that if no restrictions are placed on the value of K any number of isotopes are possible.

A statistical study of the results given above shows that the natural restrictions can be stated in the form of rules as follows:

In the nucleus of an atom there is never less than one electron to every two protons.—There is no known exception to this law. It is the expression of the fact that if an element has an atomic number N the atomic weight of its lightest isotope can not be less than $2N$. Worded as above, the ambiguity in the case of hydrogen is avoided. True atomic weights corresponding exactly to $2N$ are known in the majority of the lighter elements up to A .³⁶ Among the heavier elements the difference between the weight of the lightest isotope and the value $2N$ tends to increase with the atomic weight; in the cases of mercury it amounts to 37 units. The corresponding divergence of the *mean* atomic weights from the value $2N$ has, of course, been noticed from the beginning of the idea of atomic number.

The number of isotopes of an element and their range of atomic weight appear to have definite limits.—Since the atomic number only depends on the *net* positive charge in the nucleus there is no arithmetical reason why an element should not have any number of isotopes. So far the largest number determined with certainty is 6 in the case of krypton. It is possible that xenon has even more, but the majority of complex elements have only two each. The maximum difference between the lightest and heaviest isotope of the same element so far determined is 8 units in the cases of krypton and xenon. The greatest proportional difference, calculated on the lighter weight,

is recorded in the case of lithium, where it amounts to one-sixth. It is about one-tenth in the case of boron, neon, argon, and krypton.

The number of electrons in the nucleus tends to be even.—This rule expresses the fact that in the majority of cases even atomic number is associated with even atomic weight and odd with odd. If we consider the three groups of elements, the halogens, the inert gases, and the alkali metals, this tendency is very strongly marked. Of the halogens—odd atomic numbers—all 6 (+1?) atomic weights are odd. Of the inert gases—even atomic numbers 13 (+2?) are even and 3 odd. Of the alkali metals—odd atomic numbers—7 are odd and 1 even. In the few known cases of elements of other groups the preponderance, though not so large, is still very marked and nitrogen is the only element yet discovered to consist entirely of atoms whose nuclei contain an odd number of electrons.

If we take the natural numbers 1 to 40, we find that those not represented by known atomic weights are 2, 3, 5, 8, 13 (17), (18), 21 (33), 34 (38). It is rather remarkable that these gaps, with the exception of the four in parentheses, are represented by a simple mathematical series of which any term is the sum of the two previous terms.

In consequence of the whole number rule there is now no logical difficulty in regarding protons and electrons as the bricks out of which atoms have been constructed. An atom of atomic weight m is turned into one of atomic weight $m+1$ by the addition of a proton plus an electron. If both enter the nucleus, the new element will be an isotope of the old one, for the nuclear charge has not been altered. On the other hand, if the proton alone enters the nucleus and the electron remains outside, an element of next higher atomic number will be formed. If both these new configurations are possible, they will represent elements of the same atomic weight but with different chemical properties. Such elements are called "isobares" and are actually known.

The case of the element hydrogen is unique; its atom appears to consist of a single proton as nucleus with one planetary electron. It is the only atom in which the nucleus is not composed of a number of protons packed exceedingly closely together. Theory indicates that when such close packing takes place the effective mass will be reduced, so that when four protons are packed together with two electrons to form the helium nucleus this will have a weight rather less than four times that of the hydrogen nucleus, which is actually the case. It has long been known that the chemical atomic weight of hydrogen was greater than one-quarter of that of helium, but so long as fractional weights were general there was no particular need to explain this fact, nor could any definite conclusions be drawn from it. The results obtained by means of the mass-spectrograph remove all doubt on this point, and no matter whether the explanation is to

be ascribed to packing or not, we may consider it absolutely certain that if hydrogen is transformed into helium a certain quantity of mass must be annihilated in the process. The cosmical importance of this conclusion is profound and the possibilities it opens for the future very remarkable, greater in fact than any suggested before by science in the whole history of the human race.

We know from Einstein's Theory of Relativity that mass and energy are interchangeable,²⁸ and that in C. G. S. units a mass m at rest may be expressed as a quantity of energy mc^2 , where c is the velocity of light. Even in the case of the smallest mass this energy is enormous. The loss of mass when a single helium nucleus is formed from free protons and electrons amounts in energy to that acquired by a charge e falling through a potential of nearly thirty million volts. If instead of considering single atoms we deal with quantities of matter in ordinary experience the figures for the energy become prodigious.

Take the case of one gram atom of hydrogen; that is to say, the quantity of hydrogen in 9 c. c. of water. If this is entirely transformed into helium the energy liberated will be

$$.0077 \times 9 \times 10^{20} = 6.93 \times 10^{18} \text{ ergs.}$$

Expressed in terms of heat this is 1.66×10^{11} calories or in terms of work 200,000 kilowatt hours. We have here at last a source of energy sufficient to account for the heat of the sun.²⁹ In this connection Eddington remarks that if only 10 per cent of the total hydrogen on the sun were transformed into helium enough energy would be liberated to maintain its present radiation for a thousand million years.

Should the research worker of the future discover some means of releasing this energy in a form which could be employed, the human race will have at its command powers beyond the dreams of scientific fiction; but the remote possibility must always be considered that the energy once liberated will be completely uncontrollable and by its intense violence detonate all neighboring substances. In this event the whole of the hydrogen on the earth might be transformed at once and the success of the experiment published at large to the universe as a new star.

In considering the spectra of isotopes there is every reason to suppose that the light emitted by an atom will depend upon the movements of its planetary electrons, and therefore upon the force controlling these—that is, the nuclear charge. We therefore expect that the difference between the spectra of two isotopes will be extremely small, since the nuclear charges are identical. This expecta-

²⁸ Eddington: "Time, Space and Gravitation," p. 146, Cambridge, 1920.

²⁹ Eddington: Brit. Assoc. address, 1920; Perrin: Scientia, Nov., 1921.

tion is borne out in practice and the difference in wave length has only been detected in the case of the isotopes of lead. Aronberg,³⁰ in 1917, discovered a shift of 0.0044 \AA between ordinary lead and a radio lead of atomic weight 206.3. This result has been confirmed by the subsequent work of Merton,³¹ who has recently measured a shift of 0.011 \AA in one of the lines of an extremely pure Carnotite lead as compared with the same line in ordinary lead. These shifts, though extremely minute, are, however, hundreds of times larger than the ones predicted by the simple application of the Bohr theory.

The artificial separation of the isotopes of nonradioactive elements is an exceedingly difficult operation; indeed, had it been otherwise they must have been discovered long ago. In the case of neon, already described, which is a particularly favorable one, the extreme difference between the lightest and heaviest fractions amounted to 0.13 of a unit of atomic weight. Harkins,³² using a somewhat similar diffusion method, has successfully separated the isotopic hydrochloric acids and obtained a shift of 0.055 of a unit. A beautiful method applicable to certain liquids has been developed by Bronsted and Hevesy.³³ This consists in allowing the liquid to evaporate at so low a temperature and pressure that none of the molecules escaping from its surface can ever return to it again; a concentration of the heavier constituent in the residue must then result. They first applied it to mercury, and the latest separation achieved with the isotopes of that element is indicated by the figure 0.99974 and 1.00023 for the densities of the lightest and heaviest fraction, respectively, the normal density being taken as unity. In atomic weight this separation corresponds to a shift of 0.1 of a unit. They have also applied the same method to a solution of hydrochloric acid in water and obtained a change of atomic weight of about 0.02 of a unit.

Several other methods of partial separation have been suggested, but the only ones which have been successful in practice are those mentioned above. Complete separation can be achieved by means of positive ray analysis, but the quantities to be obtained in this way are too minute to be of the slightest practical importance. The fact that many of the most familiar elements prove to be mixtures of isotopes is of fundamental theoretical importance, but when we consider the extreme difficulties of their separation it seems very unlikely, unless some entirely new method is discovered, that the numerical constants of chemistry are likely to be affected seriously for some time to come.

³⁰ Aronberg: *Proc. Nat. Acad. Sci.*, 3,710, 1917, and *Astrophys. Jour.*, 47, 96, 1918.

³¹ Merton: *Proc. Roy. Soc.*, 99A, 87, 1921.

³² Harkins and Hayes: *J. Amer. Chem. Soc.*, 43, 1803, 1921.

³³ Bronsted and Hevesy: *Phil. Mag.*, 43, 31, 1922.

MODIFYING OUR IDEAS OF NATURE: THE EINSTEIN THEORY OF RELATIVITY.¹

By HENRY NORRIS RUSSELL,
Professor of Astronomy in Princeton University.

I.

It is probably a long time since there has been any occasion on which a matter so definitely belonging to pure science as the "theory of Einstein" has excited so much popular interest.

Although the statements in the newspapers concerning "the overthrow of Newton's laws" and similar "scare heads" have gone beyond the more sober statements of scientific authorities, it is nevertheless true that the theory of relativity, of which the recent work of Einstein forms an extension, has modified our conceptions of nature in a very remarkable fashion.

Einstein's reported statement that there were not more than 12 men in the world who could read and fully understand his book was probably quite within the facts. But the elementary ideas on which the theory of relativity is based do not involve any difficult mathematics, and the only obstacle to grasping or holding them is their remarkable novelty. We can understand them easily enough, or at least understand what they are about, if only we begin at the beginning.

It probably has not occurred to all of you that while I was speaking the last sentence we traveled several hundred miles. Yet, of course, we did. If we had not, the earth would have left us behind it somewhere in empty space.

In fact, we are undergoing a very complicated series of motions, carried around with the rotating earth and swinging along much more rapidly and in a much vaster curve with its orbital motion.

But of this fact we are blissfully unconscious. Why? Because the motion is perfectly smooth, without jar or shock, and in particular because not merely we ourselves, but all the objects that constitute our environment, are moving together.

¹ Reprinted by permission from Princeton Lectures, No. 2, Princeton, N. J., May 1, 1920.

MOTION AND DISTANCE ORDINARILY MEASURED BY "TYING UP"
TO DEFINITE OBJECTS.

So we come to one of the main conceptions of the theory of relativity, the moving frame of reference.

We ordinarily refer our measurements and indeed our notions of distance and of motion to some frame, what the mathematician would call some system of co-ordinates, which, so to speak, is "tied" to some definite objects—ordinarily to that portion of the earth's surface on which we may have set ourselves or over which we may be traveling at the moment.

Though we and all our well-informed ancestors for two centuries have known very well that this frame of reference is not at rest but is in rapid and intricate motion, we are, nevertheless, still accustomed to referring our motions to this moving frame and saying that a thing has not budged when its position with respect to the ground has not altered.

And in doing this we not only follow the promptings of common sense, but find a practical and working basis for the scientific description of almost all terrestrial affairs.

But the moment we begin to look off the earth into space things are different. It then becomes obvious that the earth is not at rest but moving, both on its own axis and about the sun.

I say "obvious;" but it is worth remembering that these facts—at present so familiar even to the man in the street—aroused, when their truth was first advocated, the most violent disbelief and agitation, and that it took a century or more of controversy to displace the old innate belief in the fixity of the earth, that is, of our frame of reference, and substitute the belief that it was in motion.

NECESSITY OF FINDING OTHER MEANS OF MEASURING MOTION AND
DISTANCE.

So far as our solar system goes we may comfortably treat the sun as being at rest and attach our frame of reference to it. But when we come to look still farther afield at the stars we find them in motion and later detect a drifting tendency among them which indicates beyond question that our sun itself is moving.

So next we hitch our frame of reference on to a sort of average position of all the stars visible to the naked eye, and find that with respect to this new frame of reference the sun and planets are moving at the rate of about 12 miles per second in a definitely known direction.

We were content with this until within the last decade, when observations upon the nebulae, which we know now to be enormously

farther off than the naked eye stars, revealed extremely rapid motions.

If we try now to hang a frame of reference, so to speak, to the average of these nebulae, it begins to look as if our solar system was moving, compared with this, at a speed of something like 400 miles per second, which motion of course the system of stars visible to the naked eye must substantially share.

But now, which of all these systems is really moving?

Are the stars at rest and the nebulae moving, or are the nebulae at rest and the stars moving, or are they both moving past each other in different directions, and is there anything at rest? Can we really find anything anywhere in the material universe upon which we can really set the feet of our imagination and say "*J'y suis, j'y reste*" with the conviction that we are at last upon the firm rock of the absolutely motionless?

It is from a search for an answer to this question that the theory of relativity grew.

The first great contribution was made by Newton. An immediate consequence of his fundamental principles of physical science is that if we have a number of objects moving together in space, which we may call a system, acting upon one another in any fashion, however complicated, but free from outside influence, then the relative motions of the bodies in that system will not depend at all upon the rate at which the system as a whole is moving through space, or the direction of its motion, but only upon the mutual interaction of its parts.

Simple uniform motion in a straight line (what we technically call a "motion of translation") does not influence the things that happen in the system at all, even to the minutest degree. Therefore an observer within the system cannot hope to detect it unless he has something outside to observe. It is on account of this great dynamic principle that we are unconscious of the motion of the earth about the sun.

In our proposed search, then, for "absolute motion" we must use some other means, and our most efficient tools are likely to be the waves of light. We know that light spreads out from any hot body into space in all directions and at the great speed of 186,000 miles a second.

TAKING THE ETHER AS A BASIS IN THE SEARCH FOR ABSOLUTE MOTION.

Despite this enormous velocity, something real actually travels outward, because it carries with it energy, which is, to the modern physicist, one of the most fundamental of all realities.

This energy may still be perceptible to our eyes or apparatus when reaching us from the stars after a journey which has consumed many thousands of years.

We know, too, that this energy, while it is on its way, travels in a manner strikingly similar to the propagation of waves, so much so that we feel justified in describing light as consisting of waves of definite lengths and properties.

Now how does this energy travel through apparently empty space with these singular wave properties? The natural answer, almost the intuitive answer, is to say that it travels through a medium, and so we invent the "ether," simply as the medium which carries the light.

But if there is such a medium in space, and light travels through it in every direction at the same speed, it would seem as if here, at last, in this undisturbed ether, we had our frame of reference which we could use as our basis for the measurement of all other motions.

DETECTION AND MEASUREMENT OF MOTION BY LIGHT SIGNALS THROUGH THE ETHER.

If this be true, we can detect whether this world of ours is moving through the ether or not by sending light signals through equal distances in different directions and seeing whether they come back to us at the same interval of time.

To see how the thing works, let us suppose first that we have an observer at rest with respect to the ether and surrounded by a circle of mirrors set in various directions from him but all at a distance of 186,000 miles.

If he then produces a flash of light at his own position this light will travel out and in one second will reach all the mirrors simultaneously, will be reflected at each and at the end of another second will come back to him simultaneously from all the mirrors. (If this hypothetical apparatus appears to you inconveniently large, you can just as well imagine one a million times smaller, which would make the radius of the circle about a thousand feet, and count your time in millionths of a second instead of whole seconds.)

So far so good. But now suppose that the observer and his whole circle of mirrors, big or small, are not at rest but are all moving together uniformly at a speed of half the velocity of light.

Now let the observer send out a light signal and wait for its reflection from that mirror which is directly on the line of his track and in the direction toward which he is moving.

The light traveling out toward this mirror would itself move 186,000 miles a second but would have a "stern chase," since the

mirror is receding half as fast as it is traveling, and it is easy to see that it would take two whole seconds to reach the mirror.

On the return journey the observer will be advancing to meet it with half the speed of light, and this part of the process will take only two-thirds of a second. The elapsed time for the round trip of the light will be two and two-thirds seconds, considerably longer than if the observer was at rest.

Consider next a ray of light which gets reflected in the mirror whose direction from the observer is at right angles to the first.

It will not have the long stern chase which the first ray has, but nevertheless it will lose something, because in order to reach the moving mirror it will have to travel "on the bias," so to speak, through space, so that it will reach not the point where the mirror was when the light started, but the point where it will be when it gets there, and something quite similar will happen on the return journey.

When this is calculated it is found that the round trip will in this case take about two and one-third seconds. (The exact amount involves calculating a square root that we need not bother with here.)

The important point is that in this case, where the observer and mirrors are moving through the ether, the ray of light which has traveled up and down the direction of motion will take a longer time for the round trip than the ray which has traveled crosswise to the motion over a path of exactly the same length.

We should, therefore, in this way be able to detect motion of our own system through the ether, and if our measurements were sufficiently accurate, determine its direction and rate.

FAILURE OF EARLY EXPERIMENTS.

This was attempted in the famous Michelson-Morley experiment. The distance of the round trip was in this case only a few feet, and the difference in time over the two paths only something like a millionth part of one billionth of a second.

But this minute interval could be measured by splitting a ray of light into two parts by letting part of it be reflected sidewise from a transparent mirror and the rest go through, and reuniting the parts after their trip.

If one had gained on the other by even a fraction of the time of vibration of a single light wave the fact could be detected, and the waves which we ordinarily call light vibrate at the rate of about six hundred thousand billion per second.

Michelson and Morley tried their experiment, and in place of the easily measurable result which they anticipated, they got nothing.

The light waves came back over the two paths in exactly the same interval of time.

They tried it again and again at different times of the year when the earth was moving in different directions around the sun, so that even though the earth might have been at rest in space on some one of these days it certainly was not at rest on all of them. But they always met the same negative result.

II. EINSTEIN'S ASSUMPTION THAT ONLY RELATIVE MOTION IS POSSIBLE OF STUDY.

Other optical experiments of a more intricate nature and even greater delicacy were attempted with the same object of detecting the motion of the earth through the ether and they all failed.

After it became clear that the trouble was not in the apparatus or the experiment, it was evidently necessary to account for the absence of the predicted effect.

After various minor hypotheses had been tried, Einstein started in with the bold assumption that these experiments had unveiled a new law of nature, viz, that the universe was so constructed that it was not possible by any physical experiment, optical or otherwise, to detect the existence of absolute, uniform, straight-ahead motion, or indeed to determine whether the observer's frame of reference was at rest or in such uniform translational motion.

If this is true, it follows that it is only the relative motions of material bodies in the universe which we can study at all.

Hence the name of the "Principle of relativity."

A second principle, following naturally from the experiments which led to the first, is that the velocity of light in empty space will always come out the same, whether measured by an observer moving, with his apparatus, in one direction at one rate or by one similarly moving in another direction and at a different rate.

NOVEL CONSEQUENCES OF EINSTEIN'S HYPOTHESIS.

This principle sounds harmless enough, but the consequences which follow from it are so different from our old preconceived opinions that they often appear to us grotesque to a degree.

Take one of the simplest ones. Let us go back to the observer with a ring of mirrors surrounding him, from all of which the reflections of his flash of light reach him at the same instant. If he thinks that he is at rest in space he will say that these mirrors are distributed around a perfect circle with his own position as center.

Now suppose he chooses a different frame of reference, in uniform motion compared with his original one. That is, suppose that he thinks that he and the mirrors together are moving uniformly in some particular direction and at a high velocity.

He will now say, "If these mirrors were really on a circle the light would take longer to reach me from those which were in the direction of my path than from those at right angles. Since the light returns simultaneously from all, the mirrors are not arranged on a circle but on an ellipse, which is longer at right angles to the direction of my motion than it is the other way."

If, as in the case previously discussed, he supposes himself to be moving with half the speed of light, he will conclude that the longer diameter of this ellipse is about fifteen per cent greater than the shorter diameter. If he estimates his own velocity higher, he will regard it as differing still more from a circle.

But although the mirrors in this case are not all at equal distances from him, he cannot find this out by measuring the distance with a measuring rod. In fact, if he does so, their distances will all appear to be exactly the same, if the principle of relativity is true. For, otherwise, by combining an optical experiment and a direct measurement he would have a method by which he could distinguish between rest and uniform motion; and this is, by the very hypothesis, impossible.

Hence nature must be so constituted that his measuring rod would automatically change in length when turned from a position parallel to his motion to one at right angles to it.

This sounds strange enough, but something of the sort is entirely necessary in order to explain the Michelson-Morley experiment. The assumption that material bodies, when moving through space, contract slightly in the direction of motion was made by Lorentz in order to explain this experiment before the more general theory had been developed. At such speeds as are actually reached by the planets in their orbits, the contraction is less than one part in one hundred million and beyond detection by anything except the most refined investigations.

We have now seen that, according to the principle of relativity, the answer to the question whether two material rods laid on the table at right angles to one another are of the same length or of different lengths depends on whether we choose to think that we and the room in which the apparatus is situated and the rest of the world, are at rest in space or are moving in different directions with high uniform speeds.

The fact that when the two rods are laid side by side they are obviously exactly equal does not prove that they are the same length when we turn them so that they make an angle with one another.

So much for the measuring of distances and the measuring of the lengths of things.

MEASUREMENT OF TIME ALSO ONLY RELATIVE.

Now how about measuring times?

Let us go back to our observer with his mirror and call him A, and suppose that at the mirror there is a second observer whom we will call B, and that both observers have clocks which run with perfect accuracy, and are able to observe the time of anything with the aid of their clocks as precisely as you please.

Now let us suppose that exactly at 12 noon A sends a flash of light out toward B. B perceives it at the instant when it is reflected by his mirror and notes the time as exactly one second past 12 o'clock. A observes the reflected signal at two seconds past 12 o'clock.

Repetitions of this signal on successive days give exactly the same result. A and B will conclude that the distance between them does not change (since it always takes light the same time to make the round trip) and that their clocks are running at the same rate.

Now suppose that A and B regard themselves as at rest. They will then agree that the distance between them is 186,000 miles, since it takes light one second to go each way, and they will also agree that their clocks are not merely running at the same rate but are exactly synchronized, because the light must have reached B just one second after it left A.

But now suppose that A and B agree in the belief that they are moving through space with half the speed of light, so that they are following the same track with B preceding A.

Using the same principle of the stern chase of which we have spoken before, they will now figure out their distance apart is not 186,000 miles, but just three-fourths as much, or 139,500 miles, and also that the light in going outward over this distance from A to B on the stern chase took one and a half seconds, whereas in coming back it occupied only one-half second.

This change in the distance amounts to exactly the same thing which we described a few moments ago; but there will be a second interesting change with respect to their measurement of time. For since they now believe that the light took one and a half seconds to go out, the time when it reached B was one and a half seconds past noon by A's clock and only one second past noon by B's clock.

Hence they will agree that B's clock is half a second fast.

On the other hand, it is easy to see that, if they had supposed themselves to be going along the same line, and at the same rate of speed, but in the opposite direction, they would have concluded that B's clock was half a second slow.

We reach, therefore, the still more picturesque conclusion that the question whether or not two events which take place at different points of space are simultaneous or occur at different times cannot be an-

swered until we have defined the uniformly moving frame of reference with respect to which we are to make our measurements and reasoning.

With the distance that we have assumed the difference between the two clocks would be only a fraction of a second even if the assumed speed was very great. But if we had taken a distance such as that between the remoter stars, whose light takes thousands of years to travel, then, according to our choice of a frame of reference, we might have been led to the conclusion that A's clock was either in agreement with B's or fast or slow by several centuries.

Once again, the possible difference between the results of different assumptions is immeasurably small for such observations as could be made upon our tiny and slowly moving earth. But for such distances as separate the stars and for greater assumed speeds they may become extremely large.

I might go on to describe what happens if we imagine two observers, A and B, receding from one another with half the speed of light and exchanging signals by a reflection back and forward from mirrors carried by both. As I have not a blackboard, I will spare you the details, which are not hard for anyone to work out who takes a pencil and piece of paper.

NEW CONCLUSIONS ABOUT SPACE AND TIME.

I will simply state the result that, given a certain set of definitely observed facts upon which both observers are entirely and perfectly agreed, it is possible that A, if he considers himself at rest, will say that B is receding from him with half the velocity of light and carrying a clock which is running at exactly the same rate as his own; while B, who naturally may prefer to think of himself as at rest and the other fellow moving, will believe that A is receding from him with half the speed of light, but will insist that his clock and A's are not keeping together but are running at different rates.

The root of this extraordinary discrepancy between their opinions will lie in the fact that they divide up the round trip time interval for the reflected light waves in different manners on account of their different assumptions as to whether the reflecting mirrors are at rest or being chased by the light, thereby introducing a difference into their methods of comparing one another's clocks which continually increases as the distance between them increases, and the round trip time for the light with it.

I have certainly gone far enough now to show you how we are led, if we stick to these apparently simple and harmless principles of relativity, into the most extraordinary conclusions with respect to space and time.

As someone has well put it, "when-ness" and "where-ness" are all mixed up together. You can't say just when a thing happened

without saying where it happened and also with respect to what frame of reference you define both when and where.

All these spectacular changes, however, reach perceptible amounts only for objects which are moving with at least a moderate fraction of the velocity of light; and the actual motion of the planets is so much slower than this that no perceptible differences will be introduced by our choosing frames of reference which are attached to the earth, the sun, the planets, or the stars.

III. RECENT ASTRONOMICAL EXPERIMENTS CONFIRM EINSTEIN'S HYPOTHESIS.

Not content with these remarkable results, Einstein proceeded a few years ago to generalize his theory further, in imagining another type of question which did not come within even the wide view of the older relativity theory.

To make this idea clear let us imagine two observers, each with his measuring instruments, means of subsistence, et cetera, in a large and perfectly impervious box, which forms his "closed system."

The first observer, with his box and its contents, alone in space, very remote from all gravitating bodies and entirely at rest.

The second observer, with his box and its contents, is, it may be imagined, near the earth or the sun or some star and falling freely under the influence of its gravitation.

To be more precise, we imagine him in what is called a "uniform gravitational field," where the gravitational force is exerted on all objects in exactly the same direction and is not converging toward the center of the attracting body, where it is always of exactly the same amount, and there is nothing to interfere with an indefinitely long fall.

This second box and its contents, including the observer, will then fall under the gravitational force, that is, get up an ever increasing speed, but at exactly the same rate, so that there will be no tendency for their relative positions to be altered.

According to Newton's principles, this will make not the slightest difference in motions of the physical objects comprising the system or their attractions on one another, so that no dynamical experiment can distinguish between the condition of the freely falling observer in the second box and the observer at rest in the first.

But once more the question arises, what could be done by an optical experiment?

According to the beliefs which have been held from the time of Maxwell, who first developed the electro-magnetic theory of light, until the present, it has generally been believed that gravitation, however powerful, has no effect whatever upon light, and that light would therefore travel in a straight line through a field of gravitational attraction exactly as it would through empty space.

EINSTEIN CONCLUDED LIGHT DOES NOT TRAVEL IN A STRAIGHT LINE.

Einstein on the other hand, assumed, just for the fun of seeing what would come of it, that the principle of relativity still applied in this case, so that it would be impossible to distinguish between the conditions of the observers in the two boxes by any optical experiment.

It can easily be seen that it follows from this new generalized relativity of Einstein that light cannot travel in a straight line in a gravitational field.

Imagine that the first observer sets up three slits, all in a straight line, at considerable distances apart. A ray of light which passes through the first and second will obviously pass exactly through the third.

Suppose the observer in the freely falling system attempts the same experiment, placing the line of his three slits at right angles to the direction in which he is falling and having them equally spaced.

The ray of light which has passed the first slit, must, in order to get through the second, move not toward the point where that slit was when it emerged from the first, but toward the point where the second slit will be when the light reaches it.

It will, therefore, be moving not at right angles to the direction in which the system is falling, but at a slant, so that during the interval in which it has traveled laterally from the first slit to the second, it will have moved downward by a certain fixed amount, namely by the amount through which the system fell in that interval.

In moving from the second to the third slit, the light will occupy the same interval of time, and, if it moves in a straight line, will go downward by the same amount as before.

But since the system is falling ever faster and faster, it will during this time interval have dropped farther than it did in the preceding time interval, and carried the third slit with it.

Hence the ray of light will strike above the third slit and fail to go through it, provided it travel in a straight line in space.

But on Einstein's assumption it must go through the third slit, since the two conditions are indistinguishable.

In consequence, the path of the light in space must be curved and not straight when gravitation is present, and the ray of light must bend downward, that is, in the direction of the gravitational force.

DEFLECTION OF LIGHT EFFECTED BY GRAVITATION.

This deduction from Einstein's new principle may thus be reached in a very simple fashion, but the further following out of the principle, and the exact calculation of its consequences is far too intricate a matter for me to speak of here.

The results, however, are not difficult to understand. The principal ones are these:

1. A ray of light passing near a gravitating body like the sun will not travel in a straight line, but will be deflected slightly downward toward the gravitating body, much as a very rapidly moving projectile would be deviated.

Calculation shows that the amount of deviation would be quite too small to measure for a ray of light that has passed near the moon or planets, but that for light that has passed near the sun the deviation reaches nearly two seconds of arc, which the modern astronomer, accustomed to accurate measurements, considers a large and very easily measurable quantity.

2. Newton's law of gravitation, on Einstein's principle, appears to be only an approximation to the true law, but an exceedingly good approximation—so much so that among all the intricate motions of the planets there is but a single case in which the introduction of the new law instead of Newton's principle produces perceptibly different consequences.

We all know the planets are moving in elliptical orbits about the sun and that the line joining the sun to the nearest point of the orbit has a certain definite position.

On Newton's theory this line would remain permanently fixed in space—always in the same direction—if it were not for the fact that the orbits of the planets are slightly but continually modified by their mutual attraction. These influences, or so-called perturbations, can, however, be accurately calculated and allowed for, so that they need not worry us here.

On the Einstein hypothesis this line to the nearest point in the orbit, or the perihelion, should not remain fixed, but should move slowly forward in the direction in which the planet is moving around the sun. The rate of its motion can be calculated from the theory when the distance and period of the planet are known. To this effect are added the influences of the attraction of the other planets as before.

It has been known for some 30 or 40 years that the perihelion of the planet Mercury, after allowance had been made for the perturbations due to the attraction of the other planets, was actually moving slowly forward in a manner which was very difficult to explain. Attempts to account for it have failed.

For example, the attraction of an unknown planet between Mercury and the sun would do the trick, but observations made during eclipses of the sun show that there is no planet there. Nor can there be a great number of small bodies whose combined attraction would do it, for these would reflect so much sunlight as to produce a bright

region in the sky, which again would have been observed during eclipses.

The discrepancy remained very puzzling until Einstein's theory appeared—and this theory predicts not only the fact and the direction of the discrepancy, but its exact amount, bringing observation and calculation into beautiful accordance.

The similar effects for the other planets are so small that they are at the very limit of measurement, but even so, the Einstein theory appears to fit the facts better than the old theory.

RESULTS OF RECENT EXPERIMENTS OF ASTRONOMERS.

This remarkable success deeply impressed astronomers, and set everyone waiting with keen interest the result of the observations made to determine whether rays of light passing near the sun were deflected.

To settle this question it is necessary to photograph stars in the immediate neighborhood of the sun, and this can be done only at the time of a total eclipse, when the moon completely hides the sun and enables us to observe the stars on a nearly dark sky.

Fortunately, the eclipse of May, 1919, afforded a very favorable opportunity for such observations. The sun was eclipsed for more than four minutes and was situated at the time in a region of the heavens remarkably full of stars bright enough to be easily photographed.

In spite of the short interval since the conclusion of the war English astronomers rose to the occasion and sent two expeditions, one to Brazil and the other to an island off the African coast, equipped with photographic instruments of high power and especially suited for the work. By extraordinary good fortune the weather was clear enough at both stations to allow the obtaining of valuable results.

Every precaution was taken to secure accuracy. For example, after the eclipse the telescope was left in place for nearly two months so that the same stars might be photographed upon a dark sky, after the sun had moved out of the way, to obtain plates showing their ordinary positions to use for comparison with the eclipse plates.

The photographs were brought to England and measured with the greatest care, and the result indicates that the apparent shift of the stars due to the deviation of the light is unquestionably present and is of very nearly, if not exactly, the amount predicted by Einstein, the difference between the observed and calculated amounts being hardly greater than the very small error which is still inherent even in these precise observations.

The observers, Professor Eddington of Cambridge and Doctor Crommelin of the Greenwich Observatory, are men of the highest

standing, and their results prove beyond a doubt the reality of the predicted effect.¹

IV. NEW THEORY BASED ON POSITIVE RESULTS.

The older form of the theory of relativity was based upon the result of very precise observations, but upon *negative* results—upon the failure to find things which ought to have been found, and easily found, provided that the older theories had been correct.

But the new extension of the theory is based upon *positive* results—the presence of an effect, in the case of the planet Mercury, which though long known baffled all explanation, and in the case of the eclipse observations, upon the presence of an unquestionable and very remarkable influence whose existence no one anticipated or imagined until it was predicted by the theory.

It therefore appears to be very strongly established.

It is true that the original form of Einstein's theory also predicted that the position of the lines of any element, such as iron, in the solar spectrum should be slightly different from those produced by the same element in the laboratory. At the present time it is very hard to say whether this effect has been observed or not.

The positions of the lines in the spectrum can indeed be measured very accurately. But there are a variety of influences at work on the sun's surface which may shift the positions of these lines, such as the pressure in the sun's atmosphere, actual motion of this atmosphere, and possibly a host of other things, so that different lines of the same element are shifted by different amounts and in spite of years of investigation of this exceedingly complex problem it is not possible yet to explain all the things that have been observed.

It is, therefore, still uncertain whether, after these other causes are allowed for, it would be found that the lines in the sun's spectrum were shifted or not. It seems probable, however, that Einstein's theory could be modified in such a manner as to account for the other effects already observed without demanding the existence of this one. Hence this can hardly be called at the present time a failure of the Einstein theory.

The mathematical expression of this last portion of Einstein's theory is the part which is so intricate and difficult.

Mathematicians, whose minds are saturated with conceptions with which the layman is utterly unfamiliar, find that these mathematical expressions may be (to them at least) most simply described in terms of space of four dimensions, or even of five dimensions in certain cases.

¹ See "A determination of the deflection of light by the sun's gravitational field, from observations made at the total eclipse of May 29, 1919," by Dyson, Eddington, and Davidson. Smithsonian Report for 1919, pp. 133-176.

This side of the subject, although deeply interesting to the mathematician, and also to the philosopher, is not a matter of practical concern, principally for the reason that it does not deal with the facts of nature themselves, but entirely with the mathematical language which we employ in describing them.

FUNDAMENTALS OF EINSTEIN'S THEORY SUMMARIZED.

The fundamental physical facts concerning nature which have developed in connection with the theory of relativity may be briefly and somewhat crudely stated in this fashion:

1. Our methods of measuring space and time are tied up with our assumption as to whether and in what direction we are moving in a manner which, if we assume our motion to be very rapid, greatly modifies the results of these measurements, but which, for motions that are not more rapid than those of the planets or at most of the stars, produce no difference in these measurements which could be detected except by the most delicate and refined methods of observation, and usually not even a difference great enough to be so detected.

2. The new conceptions are, therefore, of very little or no importance to the practical man, but are of very great interest to the philosopher, since they indicate that the old traditional conceptions of space and time are not the only conceptions of this sort which the human mind is capable of forming, and, what is more, that when the comparison is made very precise these newer and apparently bizarre conceptions of space and time fit the facts of nature more closely than the simple common sense ones.

3. It has more recently been shown that the previous assumption that gravitation and the motion of material bodies on the one hand, and electricity, magnetism, and light on the other, formed two separate sides of nature, not connected with one another, is incorrect. These two great complexes of natural phenomena and forces are actually parts of one still greater whole, although the connection between them is of such a character that it produces measurable results in only a very few cases.

The theory of relativity does not supersede the older scientific conceptions or destroy them, but leaves them as very close and very useful approximations to the facts of nature. As is usually the case with great scientific advances, it leaves us with a view of nature which is more complex and harder to understand and to work with than our previous conceptions, but which at the same time reduces what previously appeared to be disconnected things to manifestations of a single underlying unity of principle.

THE ALKALI PROBLEM IN IRRIGATION.

By CARL S. SCOFIELD,

United States Department of Agriculture.

[With 3 plates.]

Soon after gold was discovered in California a large number of Americans undertook to reach the new El Dorado by crossing what was then known as the Great American Desert. The two or three trails across this 2,000 miles of wilderness proved difficult enough to try the endurance of the strongest. In the broad plains and dry valleys the dust was annoying and the water was often scarce and bad. These irritating and disappointing features of the region were so important and so serious that they became widely known and the word alkali soon came into general use to describe the dust and water of the arid West.

This word now passes current in our literature as applying generally to the salts that are often found in abundance in arid lands. While the major portion of these salts are not really alkaline in reaction the term is so well known and so widely used that we must recognize its validity.

Following the rush of gold seekers to California, pioneers began to settle in the desert and to practice irrigation. For them the word alkali came to have a special interest and significance. Some of the water that was used for irrigation proved to be detrimental rather than helpful to their crops and the land upon which such water had been used soon became unfit for crop production, even when better water was substituted. Thus in the progress of time, and with improved methods of transportation, alkali dust and water became less of a problem to the traveler but remained a problem to the desert farmer.

Save in a few exceptional localities, alkali is now or is likely to become a serious problem wherever irrigation is practiced. It has been the primary cause of the abandonment of large areas of irrigated land both in this country and in the Old World. The injurious effects of alkali are manifested in several different ways and

the nature and causes of these different results have not always been easy to understand or to explain.

THE IMPORTANT ALKALI SALTS.

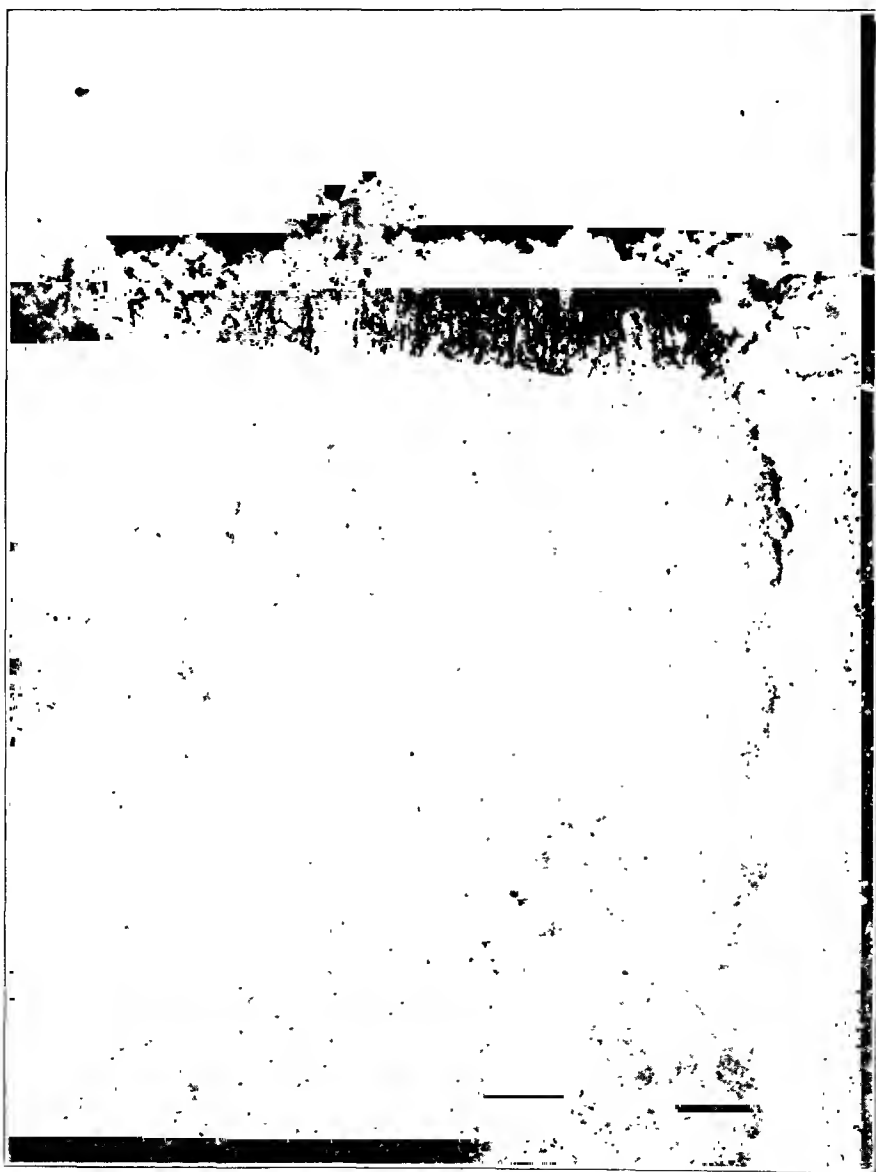
The so-called alkali salts include sodium chloride, or common salt, sodium sulphate, sodium carbonate, and sodium bicarbonate, together with some calcium and magnesium and even some potassium, combined usually as the carbonate or sulphate. There is wide variation in the proportions in which these salts occur, but they are usually all present. When sodium carbonate is abundant, it often causes a dark colored deposit on the soil surface, in consequence of which the term "black alkali" is used in reference to this salt. Sodium sulphate, on the other hand, often produces a white efflorescence on the surface of the soil and is known as "white alkali."

THE ORIGIN OF ALKALI SALTS.

These salts are derived from the disintegration and weathering of rocks in the process of soil formation. They are formed not only in arid regions but in humid regions as well. In humid regions, however, they are leached from the soil by the rain as soon as they become soluble and are carried away by the rivers to the sea. In arid regions where the rainfall is insufficient to leach the soil completely the salts remain and accumulate.

In the course of time these soluble salts are moved about by such rain as falls. As the rains gather into small streams that form temporary pools or lakes, the salts are carried into these and left behind when the water evaporates. In some places it is possible to trace very clearly the course of events in the formation of the soil in the dry country. A cross section of the soil will show alternate layers of salt and earthy material. It is clear that this material was laid down in a basin that was subject to flooding after torrential rains. These floods of muddy water spread out over the floor of the basin and the water was soon evaporated, leaving the mud and salt behind. As the last of the water evaporated from the surface of the mud layer it left a crust of salt on this surface. The next flood brought down more mud, which covered the previous layer, and some of the less soluble salts remained between the successive layers of mud, while the more soluble salts were redissolved, only to be redeposited again at the new surface.

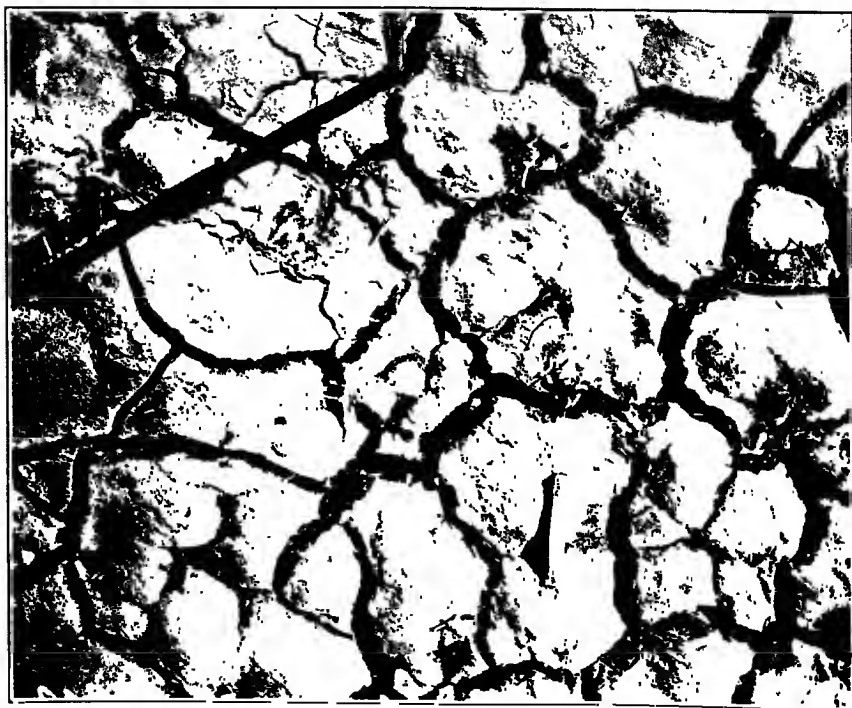
With the changing conditions of flood channels and drainage these surface deposits of salt have been reworked many times even in our most recent geological periods. Thus we find in arid regions that the soluble salts which we call alkali are abundant in some spots while virtually absent in large areas of the better-drained land.



A SECTION OF SOIL THAT HAD BEEN SATURATED WITH WATER CONTAINING DISSOLVED SALTS. WHEN THE WATER WAS EVAPORATED FROM THE SOIL THE SALTS WERE DEPOSITED ON THE SURFACE IN CRYSTALLINE FORM.



1. A LOW SPOT IN THE DESERT, IN WHICH THE FLOOD WATERS FROM THE OCCASIONAL SHOWERS HAVE EVAPORATED FOR MANY YEARS, LEAVING A HEAVY DEPOSIT OF SALTS WHICH WERE FORMED FROM THE SLOW WEATHERING OF THE SOIL OF THE PLAIN AND THE SURROUNDING HILLS.



2. A PORTION OF THE SURFACE OF THE SOIL IN THE DESERT THAT HAS DRIED RAPIDLY AFTER WETTING AND, IN DRYING, HAS FORMED SHRINKAGE CRACKS, FROM THE SIDES OF WHICH THE SOIL WATER IS VAPORIZED. UNDER SUCH CONDITIONS A LARGE PROPORTION OF THE SALTS DISSOLVED IN THE SOIL SOLUTION ARE PRECIPITATED WITHIN THE SOIL MASS RATHER THAN ON THE SURFACE.



A "HARD SPOT" IN AN IRRIGATED FIELD WHERE THE SOIL HAD BEEN PUDDLED BY THE IRRIGATION WATER AND HAD BAKED ON DRYING OUT. THE HARD CRUST IS OFTEN TWO OR THREE INCHES THICK. WHEN SUCH A CRUST IS FORMED ON NEWLY SEEDED LAND THE SEEDLINGS ARE PREVENTED FROM COMING UP.

The way in which the soluble salts are deposited from evaporating water at the surface of the soil is shown in plate 1. In this case a deep layer of soil that had been soaked with salty water dried out by surface evaporation. The water moving upward carried the dissolved salts with it until it was vaporized at the surface, when the salts were deposited in crystalline form.

Another example of the surface deposition of salts in the dry country may be seen in the flat valleys of rivers or creeks. Many desert streams meander through such valleys and where the subsoil on either bank is readily permeable to water there is an appreciable lateral seepage from the stream bed, particularly in times of high water. Some of the water from this underflow is drawn upward through the layers of soil and evaporated, leaving its dissolved salts behind. In the course of time, these surface accumulations of salt reach such concentrations as to prevent the growth of plants and thus render useless large areas of potentially fertile and easily irrigable land.

From these examples it may be seen that the alkali salts of arid lands owe their origin chiefly to the natural processes of soil weathering. The marked irregularities of their distribution are due to subsequent transportation in water and their deposition at the places where the water evaporates.

The processes of soil formation from the breaking up of rock masses proceed very slowly, so that the release of soluble salts to the soil water takes place gradually. The abundant deposits of alkali salts that are now to be found in spots in the desert may represent the accumulations of many centuries of time and the drainage from many square miles of surface. If these salts were evenly distributed throughout the region in which they were formed they would seldom be harmful, but when the salts from many acres are all deposited in a small spot they are likely to prove troublesome if that spot is selected for crop production. An example of the accumulation of salts in a low spot in the desert is shown in plate 2, figure 1. Such a low spot as this may serve for many years as an evaporating basin for the flood waters that bring in the salts from the surrounding land. After a time such a basin may be completely filled and covered by drifting soil only to be discovered later when an attempt is made to use the land for crop production. Often these spots are small in area, covering only a few acres, but in other cases such as the Great Salt Lake in Utah the evaporating basin covers many square miles.

ALKALI SALTS AND THE GROUND WATER.

The alkali salts of the desert have little practical significance except in relation to the ground water. It is only when they are dis-

solved in the ground water that they can be transported from place to place, and it is only as they occur in solution that they have a harmful effect on the growth of plants or on the physical character of the soil. For these reasons the alkali problem is always a problem of the ground water or the soil solution.

To understand the alkali problem one must understand something of the conditions which influence the movements and the reactions of the soil solution in relation to the soil. Water exists in and moves through the soil in the liquid form and as a vapor. It is only in the liquid form that it is capable of dissolving and transporting salts.

The water content of the soil varies within wide limits. A saturated soil may hold a quantity of water equal to half its own weight. A soil that is thought of as being dry when examined in the field may have as much as 8 or 9 per cent of water, in case of a very fine soil, or not more than 2 or 3 per cent of water in the case of a sandy soil. When in good condition to support plant growth, ordinary soils contain from 10 to 30 per cent of water. These figures are given to show that if the water contained in a certain quantity of soil has dissolved in it a certain quantity of salts, the concentration of the solution may vary within wide limits as the soil approaches the air-dry limit on the one hand or the saturation limit on the other.

It is probably because of this variation in the moisture content of the soil that it is customary to refer to the proportion of alkali salts as a percentage of the dry weight of the soil rather than to speak of the concentration of the soil solution. Thus in classifying or mapping alkali soils, it is the custom to describe the different areas as containing 1 per cent or 2 per cent of salts, meaning by this that the proportion of water soluble material is equal to 1 per cent or 2 per cent of the dry weight of the soil.

The concentration of the salts in the soil solution is a very different thing from the percentage of salts in the soil. Thus if a soil contained 1 per cent of soluble salts and 25 per cent of water, the concentration of the soil solution would be equivalent to 4 per cent, while if the same soil were merely permitted to dry out until it contained only 10 per cent of water, the concentration of the soil solution would be equivalent to 10 per cent. These figures give something of an idea of the concentrations of salt that may be tolerated by certain desert plants which are able through special adaptations to grow in soils containing as much as 3 per cent of soluble salts, and which are subject to periods of drought during which the moisture content may be reduced to 10 per cent or less.

It has been noted above that the soluble salts are dissolved in and move with the liquid water of the soil, and that when the soil solution is evaporated from the surface of the soil, the salts are left be-

hind, forming a crust of crystals. As a matter of fact, under field conditions, much of the water lost by evaporation from the soil is actually vaporized within the soil mass, passing upward to the free air through cracks and interstices of the soil. Where this takes place the salts are, of course, left behind at the point where vaporization takes place, which may be well below the actual surface of the soil. When saturated soil dries rapidly, particularly if it is rich in clay, it shrinks and cracks as is shown in plate 2, figure 2. In such a soil the proportion of the dissolved salts finally deposited on the surface may be very small.

In some irrigated sections conditions are such that the subsoil becomes saturated with water and there exists what is known as a ground-water table. This condition occurs naturally in some of the alluvial valleys of desert streams such as the Nile in Egypt and the Colorado and Rio Grande in this country. In other cases the ground-water table comes into existence as the result of the downward percolation of some of the water applied in irrigation, together with the seepage from canals. When the ground-water table is high—that is, when the plane of saturation is within a few feet of the surface of the soil—there may be established a capillary connection with the surface so that some of the ground water is lost by evaporation. Where this condition exists there is almost certain to be an accumulation of salts at or near the surface and consequent injury to crop plants or to the physical condition of the soil.

As a matter of fact, in the great majority of cases in which alkali salts cause trouble in irrigated lands, this trouble is associated with a high ground-water table. It is obvious that this must be so, for with a permeable soil and no ground-water table it would be very easy to wash the excess of soluble salts out of the surface layer of the soil and well below the root zone of crop plants by the simple expedient of a short period of heavy irrigation.

From these considerations it may be concluded that the troublesome accumulation of alkali salts in irrigated land is due to one of two conditions, either the ground-water table is too close to the surface or the soil is not readily permeable to water.

INJURIOUS EFFECTS ON PLANTS.

When the concentration of the soil solution becomes excessive, the alkali salts which occur in irrigated lands have a toxic or injurious effect on crop plants. The limits of toleration for crop plants is variable, depending on the nature of the salt, the kind of plant, and the stage of growth of the plant when the high concentrations occur. In some cases the injury caused by the alkali salts is probably due to the purely physical effect of interfering with the osmotic action by which the plant roots absorb water from the soil solution.

In other cases there are doubtless internal derangements of the plant's nutrition which interfere with its normal growth. In still other cases, particularly when sodium carbonate is an important constituent of the salt complex, it has been observed that actual corrosion of the plant tissues takes place.

It is sometimes difficult to determine the extent to which the alkali salts are responsible for certain nonparasitic diseases which are often serious, particularly with orchard fruits, on irrigated lands. Ordinarily the symptoms induced by these salts are easy to identify. In any field where salts are troublesome the concentration is so much greater in some spots than in others that the growth of the crop is very uneven. There may be some spots in which there is no growth at all because the salt concentration was so great as to prevent the germination of the seed or to kill the young plants before growth started. Other spots may be found where the plants remain small, as though suffering from lack of water.

These irregularities of growth of plants in fields apparently uniform as to soil conditions, together with the well-known fact that some kinds of plants are much more tolerant to alkali salts than others, have led to many attempts to overcome the alkali problem by selecting varieties or species of plants for use on alkali lands. The success of such work has been hampered by the fact that when soil or ground-water conditions are such as to favor the accumulation of alkali salts the concentration may soon be carried to a point which exceeds the limits of tolerance of the most promising species. On the other hand, some modification of the conditions may take place with the result that the salt concentrations will fall well below the limits of a wide range of crop plants.

It appears to have been the general experience that the better way to deal with the alkali problem is to remove the salts or prevent their accumulation rather than to attempt to meet the difficulty by the use of special crops or varieties. It is true that there are certain kinds of crop plants that are so sensitive to alkali salts that their production is quite out of the question on ordinary irrigated land. But there remains a very large number of crops that do well if the concentration of the soil solution can be kept within reasonable limits.

In actual field experience it has been found that when the salt content of the soil is much above one-half of 1 per cent it requires special care to use it for general crop production. This quantity of salt is really very large when expressed in terms of tons per acre. It is usually estimated that an acre of soil 1 foot deep weighs about 4,000,000 pounds, so that when a tract of land is said to contain one-half of 1 per cent of salt it means that it contains 10 tons of salt per acre for each foot in depth to which that percentage of salt extends.

Thus, if the figures apply to the first 3 feet of soil it would mean that there would be 30 tons of salt per acre dissolved in the soil water within the root zone of crop plants. For purposes of comparison it may be said that in the use of chemical fertilizers it is not customary to apply more than 400 or 500 pounds of soluble material per acre and often much smaller quantities.

THE EFFECT OF ALKALI ON THE SOIL.

In the practice of irrigation where water is applied artificially to the soil it is important that the water so applied shall soak into the ground within a reasonable time. In other words the soil must be readily permeable to water. When the soil is permeable to water and water can be used freely without swamping the land there need be no anxiety about danger from alkali salts. These will be carried away by the irrigation water just as in humid climates the direct rainfall leaches the major portion of the soluble material from the soil.

The most critical and dangerous feature of the alkali problem on irrigated land lies in the fact that under certain conditions the alkali salts affect the soil in such a way that it becomes relatively impermeable to water, or, as the saying is, it does not take water well. When this condition is encountered the alkali problem becomes immediately acute. Such conditions are found to occur in certain desert soils that have been in times past subjected to the action of salt, or they may develop in irrigated land as the result of the accumulation of salts through improper irrigation or the lack of adequate drainage. This effect of alkali salts on the soil is manifested in several ways. It may cause the surface soil to run together or become "puddled" when wet, forming a compact and gelatinous mass which holds the water from soaking downward. It may cause the formation of a layer a little below the surface of the soil which checks the downward movement of the water. This formation is known as a hardpan.

When the conditions are such that the surface soil becomes puddled by irrigation it usually becomes very hard on drying out and "bakes" so that it is difficult to work into good tilth. This condition is aggravated if the drying is rapid, as it frequently is in hot weather in a desert country. An example of this baking of a puddled soil is shown in plate 3. The formation of such a hard crust as a result of irrigation is particularly serious when it occurs after a crop has been seeded and before the seedlings have emerged.

These conditions of impermeability to water and of hardness on drying most commonly occur on land that is not very salty. For that reason these conditions have not always been regarded as a phase of the alkali problem. In general, land that is very salty takes water

well and when dry is often very soft and easy to pulverize. But as the excess salt is leached away by irrigation the symptoms described above are likely to appear.

The direct consequence of the puddled condition, or the formation of a hardpan in the soil, is that the normal movement of water is impeded and the crop plants are unable to obtain the supply needed for their growth. Thus it is found that the plants in an irrigated field may be suffering for water during critical periods though the ground has been irrigated frequently. Instances have been observed where after a season of normal irrigation the water has not penetrated into the soil more than a few inches beyond the depth to which it had been broken by the plow. Under such conditions it is not possible for crop plants to do well.

The way in which the alkali salts cause the soil to puddle and bake is through a chemical reaction with the clay or finely divided portion of the soil. This clay is essentially a compound of alumina and silica. Its chemical composition varies within rather wide limits both as to the proportions of the two substances named and as to the kinds and quantities of other elements, chiefly bases, combined with them. Clay is not soluble in pure water, but when acted upon by solutions of the salts of sodium or potassium some chemical changes appear to take place which influence profoundly its physical reactions.

When the clay of the soil has been acted upon by solutions of sodium salts, and particularly by sodium carbonate, some of the sodium combines with some of the silica of the clay and forms a so-called colloidal substance very similar in character to water glass. This substance remains nearly or quite insoluble and inert as long as the soil solution contains appreciable quantities of sulphates or chlorides. If these are leached away the colloidal silicates combine with the soil water and become gelatinous. When this takes place it works a profound change in the physical character of the soil, particularly in relation to its absorption of water and its condition on drying.

The salts of calcium and magnesium do not form soluble or colloidal compounds with the silica of the soil, and consequently they take no part in injuring the physical condition of the soil. In fact, there is reason for believing that these latter salts tend to retard the deleterious action of the sodium salts.

THE QUALITY OF IRRIGATION WATER.

In most of the places where irrigation is undertaken there is more irrigable land than there is water to irrigate it, so that it is possible to use the water on the better land. Where this condition exists the alkali problem can be avoided at first by leaving the alkali spots

untouched. Were the alkali problem in irrigation confined to the reclamation of those lands in which an excess of salts had accumulated under natural conditions it would be much less serious and would cause much less apprehension as to the future of irrigation farming.

The really serious aspect of the alkali problem lies in the fact that in a majority of instances it develops after a period of successful irrigation, after the land has been leveled and improved with roads, fences, and farm homes. When this happens the real cause of the trouble is to be sought in the quality of the irrigation water rather than in the quality of the land.

The water used for irrigation is taken from streams or from wells. All such water contains at least a small quantity of salt in solution. In general the stream and underground waters of arid regions contain more dissolved salts than the waters of humid regions. The river waters of typical humid regions usually carry less than 200 parts of dissolved salts in a million parts of water, while many streams of the arid regions carry more than 1,000 parts of salt per million. Ocean water contains about 35,000 parts of salt per million. For purposes of comparison it may be said that an acre-foot of water, that is, the quantity required to cover 1 acre 1 foot in depth, weighs about 2,750,000 pounds. In ordinary irrigation practice, it is not uncommon to use as much as 3 or 4 acre-feet of water per acre per year. From these figures it will be seen that if all the salt carried in the irrigation water were retained in the soil the annual increment of salt might be as much as 4 or 5 tons per acre.

These figures serve to illustrate the importance of considering the quality of irrigation water in relation to its long continued use on the same land. If conditions are such that a fair proportion of the water applied percolates downward through the soil and eventually finds its way out in the country drainage, the excess of salts may be carried away with it. But if, on the other hand, conditions are such that most of the water applied is held in or near the surface soil and evaporates there, its burden of salts will be left behind and in time the accumulation must reach and pass the danger limit.

Another feature of the quality of irrigation water that is quite as important as its salt content is the relative proportions of the different salts. Where the dissolved salts are largely compounds of calcium and magnesium the injurious effect, if any, is confined to plant growth and may be remedied, when it becomes apparent, by suitable measures of artificial drainage. But if the salts are largely compounds of sodium or potassium there is always serious danger that the physical condition of the soil may be injured to such an extent that it will remain unproductive even after the excess of salt has been removed by drainage.

The artificial drainage of irrigated land is sometimes nearly as expensive as the construction of the irrigation system. And, in many cases, it is no less essential. Where the drainage system, either natural or artificial, functions properly there should be no excessive accumulation of alkali salts in irrigated land unless the soil becomes so impermeable that the irrigation water can not get through it. Undoubtedly there are instances at present, and there have been many in the past, where irrigated land has become impermeable and unproductive as a result of the use of water containing much more sodium than calcium and magnesium. Such impermeability may develop in the ordinary course of careful irrigation and without the appearance of the usual symptoms of a alkali injury such as the swamping of the land or the accumulation of salts beyond the toxic limits of plants. More often this condition of impermeability sets in after the land has been swamped with salty water as a result of excessive irrigation with inadequate drainage and an attempt is made to reclaim the injured land by improving the drainage conditions.

THE PERMANENCE OF IRRIGATION AGRICULTURE.

Irrigation has been practiced since the earliest historic times. The Garden of Eden and the gardens of Babylon were located in the desert valley of the Tigris and the Euphrates and were watered artificially. The valley of the Nile has been irrigated for thousands of years and its irrigated area is being extended almost continually. In the Transcaspiian region of southwestern Asia there are numerous places where irrigation prospered for some years and was then abandoned.

In our own country, where irrigation was begun about three-quarters of a century ago, there are places where it has continued to be successful on the same land and many other places where, after a few years, the land has become unfit for crop production and it has been necessary to conduct the water to other lands or let it go unused.

It is clear that one must be cautious in generalizing about the permanence of irrigation. We lack essential information particularly concerning many of the cases where it has been abandoned. We know that many of the failures may be traced directly to the excessive accumulation of alkali salts. In other places the outstanding feature has been high ground-water due to inadequate drainage with alkali troubles less conspicuous. No doubt changing economic conditions have been the determining factors in still other cases.

In the case of Egypt, which is probably the best example of long continued and successful irrigation, there is reason for believing

that continued prosperity has been due to the quality of the water supply. The water of the Nile is probably lower in salt content than any other used extensively for irrigation. This water carries during the flood season less than 150 parts per million of dissolved salts, and about 75 per cent of these salts are compounds of calcium and magnesium. Furthermore, the ancient system of irrigation, which has been gradually replaced during the last half century, was one in which it was absolutely essential to have an adequate drainage system through which to draw off the water from the flooded basins. As a result there was only a short period each year when the flood waters percolated into the subsoil. With perennial irrigation the subsoil has gradually become filled with water and its relief calls for a much more comprehensive and expensive type of drainage.

In some of our own irrigation enterprises there exists a very different set of conditions. Some of our important irrigation streams carry more than 1,000 parts per million of dissolved salts, of which more than half are compounds of sodium. Too often irrigation has been undertaken without making any provision for drainage until the need for drainage became painfully apparent. In other situations where the water supply has been inadequate, or where it has been necessary to lift it for long distances to reach suitable lands, it has been used so sparingly that all the water applied has been used by crop plants or evaporated from the soil surface. Under such conditions it is inevitable that the salts carried to the land by the water must remain in the upper layers of the soil and finally reach concentrations that become toxic to the plants or by reacting with the soil produce a condition of impermeability.

There is no sound reason for doubting that irrigation farming can be made as safe and as permanent as any other kind of farming if the essential conditions are complied with. In attempting to understand these conditions we may learn some useful lessons from the history of ancient irrigation enterprises as well as from the careful observation of the tendencies in more recent projects. There can be little doubt that the same fundamental laws of physics and chemistry that are operating now have been operating during ages long past. When the balance of salts in the irrigation water has been such that the permeability of the soil has been impaired by its use, the accumulation of salts has in time made crop production impossible. Such results have occurred in the past and are taking place at present.

While the alkali problem presents many difficulties and complications it is by no means insurmountable. Experience and scientific investigation are both contributing the knowledge with which the problem may be solved.

AN OUTLINE OF GEOPHYSICAL-CHEMICAL PROBLEMS.¹

By ROBERT B. SOSMAN,

Geophysical Laboratory, Carnegie Institution of Washington.

The subject-matter of geophysical-chemistry may be defined as "the physical properties and chemical reactions of the substances and aggregates that make up the earth." It may therefore be roughly divided into two parts: A. Properties and reactions of materials accessible at the earth's surface. B. Properties and reactions of materials in the earth's interior.

Each of these may again be subdivided as follows:

1. Properties and reactions of individual chemical substances; for example, the silicate minerals.
2. Properties and reactions of aggregates; for example, oceanic water, silicate rocks.
3. Properties and reactions of larger units of matter; for example, glaciers, batholiths.

A. MATERIALS AT THE EARTH'S SURFACE.

CHEMICAL SUBSTANCES.

A relatively small number of "common" oxides serves to make up practically 98 per cent by weight of the outer 10 miles of the lithosphere. All the other elements and compounds known to chemistry are included in the remaining 2 per cent. From the geochemical standpoint, therefore, we may divide chemical substances into two classes, "abundant" and "rare."

The "abundant" oxides are, in the order given by averages of a great many analyses of terrestrial rocks, as follows:

SiO_2 About 60 per cent by weight.

Al_2O_3 About 15 per cent by weight.

$\left. \begin{array}{l} \text{FeO} \\ \text{Fe}_2\text{O}_3 \end{array} \right\}$ About 6 per cent by weight.

¹ Reprinted by permission from the Proceedings of the National Academy of Sciences, vol. 6, No. 10, pp. 592-601, October, 1920.

CaO	About 4.9 per cent by weight.
MgO	About 3.7 per cent by weight.
Na ₂ O	About 3.3 per cent by weight.
K ₂ O	About 3.0 per cent by weight.
H ₂ O	About 2.0 per cent by weight.
CO ₂	About 0.7 per cent by weight.

An understanding of the chemistry of these oxides and their combinations is essential to the progress of petrology. Their study should proceed from the simple to the complex, i. e., should begin with the individual oxides, then proceed to their two-component systems, then the ternary systems, and so on. Upon this fundamental basis is then erected the structure of physical properties for each system—densities at all accessible temperatures, mechanical properties, fluidity, surface tension, specific and latent heats, etc.

The study of these systems may be divided on practical grounds into (1) investigations of the anhydrous oxides and silicates (taking in the first eight oxides in the list above); (2) investigations involving *hydrous* silicates, as well as combinations containing both carbon dioxide and water.

(1) *Anhydrous silicates*.—Work on the first group involves high-temperature researches under ordinary atmospheric pressure conditions, except in the case of systems containing the oxides of iron, where the oxygen pressure must be controlled, and systems containing the alkali silicates, where attention to moisture, carbon dioxide, and volatility of the oxides is necessary in certain cases. Considerable progress has been made in the study of the anhydrous silicates. The phase rule diagrams of the four ternary systems of SiO₂, Al₂O₃, MgO, and CaO are now complete, and a large amount of data is at hand on the alkali feldspars, the forms of silica, portions of several quaternary silicate systems, etc.

(2) *Silicates with volatile components*.—Work on systems involving the volatile components CO₂ and H₂O must be done, for the most part, under pressure, and with apparatus designed especially for this purpose. The methods are well in hand and progress is being made in assembling experimental data. The theoretical side, involving the complications due to pressure as a variable in addition to temperature, is also being carried forward by several investigators.

So much for the 98 per cent. But the remaining 2 per cent contains many natural substances of such great economic as well as geologic interest that they must also receive attention. These may be roughly classified as in the following examples:

The sulfide ores (e. g., sulfides of iron, nickel, zinc, copper, lead, cobalt, cadmium, mercury, silver).—These must be studied both in

their dry melts (to obtain their fundamental characteristics) and in relation to water solutions under atmospheric pressure (problems of oxidation and secondary enrichment). A distinct problem of the sulfides is their relation to the silicates in the igneous rocks (differentiation of sulfide-bearing bodies, as at Sudbury, Ontario).

Volcanic gases and salts.—These are of particular interest in their relation to volcanic activity, as at Kilauea and Vesuvius. Research on gases, including the various gas mixtures evolved from volcanic vents, is of a peculiarly trying character on account of the invisibility and intangibility of the substances handled, as well as the difficulty of collecting and transporting samples of the natural products. A special phase of this work is the study of the complex gases given off by fumaroles and hot springs. In addition to chemical composition and equilibria of the gases, data are needed on the physics of the flow of such gases from vents, as related to volume, temperature, and pressure at the point of emission.

The volcanic "sublimates," such as sulfur, ammonium chloride, arsenic sulfide, copper chloride, magnetite, may be mentioned in this connection, as well as the minerals accompanying fumarole and hot-spring activity.

The oxide ores (e. g., ores of iron, chromium, manganese, tin).—The study of these ores involves high-temperature investigations similar to those on the silicates, and also studies of the hydrated and colloidal oxides.

The natural hydrocarbons.—Organic chemistry of a very complex kind is involved in the formation and alteration of natural gas and petroleum, and many problems of physics and physical chemistry, such as adsorption, surface tension, and colloid phenomena, are also involved in their underground storage and movements.

Other substances—for example, the silicate ores, the carbonate ores, the titanium minerals—may be similarly grouped for purposes of experimental study, but it is hardly necessary here to make a complete inventory of such groups.

Running along with all these investigations is the general research necessary to develop experimental methods and apparatus, and to keep the general theory of physics and chemistry abreast of the newly accumulated facts.

AGGREGATES.

In the preceding paragraphs we have mentioned some of the researches that are necessary on the chemical *substances* of the earth's surface. We come next to *aggregates*, including the igneous rocks, the pyroclastic and sedimentary rocks, the oceans and other bodies of water, and the atmosphere.

Igneous rocks and magmas.—Among the aggregates the igneous rocks are the most important, constituting as they do the original matter from which the others have been derived. They are poly-component systems with seldom fewer than six oxides, and it seems out of the question at present to give a complete phase-rule discussion of the chemistry of any such complex system. It does seem possible, however, to cover the field of actually occurring rocks by partial systems based upon stable minerals, themselves combinations of two or more oxides.

Experimental work has progressed far enough to show that the fusion and solidification phenomena of the igneous rocks are capable of systematic treatment of the kind mentioned above, even when the volatile components H_2O and CO_2 are included.

Following this fundamental information on the fusion diagrams, we must know the densities of the igneous rocks and their magmas at all temperatures, with their changes of volume during solidification, the textures and structures produced by various conditions of solidification, the latent heats concerned in fusion of the magma and in assimilation by it of other rocks, and many other physico-chemical data.

Some of the phenomena of differentiation of silicate rocks are probably to be treated as results of simple crystallization backed up by the effects of gravity in causing sinking or flotation of crystals. This is the only method of differentiation that has been experimentally proven, but the separation of two or more liquid phases, and perhaps other phenomena also, may take part in this little-known process.

The phenomena of the movements of igneous magmas in the lithosphere must next be attacked. This involves studies of viscosity and its changes with temperature; energy transfers accompanying movement, including perhaps the conversion of potential gravitational energy into heat energy by movement; differentiation due to movement, and the effects of the separation of gaseous constituents in causing differentiation, movements of magmas, and transfers of energy.

While the igneous rock is solidifying, processes of metamorphism may go on as a result of the passage of its more volatile constituents through the igneous rock itself and through its bordering rocks. The rise of temperature in the inclosing rocks will also initiate reactions and movements of material. The chemistry of these processes (alteration, serpentization, contact metamorphism and replacement, formation of pneumatolytic dikes and veins) will have been included under the chemistry of the silicates with volatile components, but the rates of the reactions and the transfers of energy accompanying them must be studied as a separate problem. The ques-

tion of the permeability of crystalline substances to volatile components may perhaps arise. Studies of the inversion of polymorphic forms, properties of liquid inclusions, and the effects of increased temperature on neighboring rocks must be made in order to obtain data on the original temperature of the magmas.

Sedimentary rocks.—No sooner does the solidified igneous rock find itself at or near the earth's surface than it becomes the object of the group of processes known as "weathering." This is a subject that has been nearly at a standstill since the publication of Merrill's "Rocks, rock weathering, and soils" about 15 years ago, which summarized our knowledge up to that date. It involves physical factors such as the disintegrating action of periodically fluctuating temperatures, together with the study of relative rates of reaction within and in the presence of dilute water solutions, with the complications due to colloidal phenomena and reaction in capillary spaces—a difficult field and one worthy of well-planned effort.

Rock disintegration, corrasion, and transportation, included in the general process of erosion, bring in physical and mechanical problems such as the rounding of fragments by attrition; their sorting by air and water movements; their distribution and redistribution through the agency of winds, currents, and waves; the production of particular structures, such as ripple marks; the movement of unconsolidated sediments as in sand dunes, soil creep, and solifluxion; and similar questions. Reference need only be made here to summaries of these problems by Vaughan and by Merwin before the Geological Society of America in December, 1919. Experimental physics will be found deeply involved in all such problems. Colloidal chemistry will also enter, as, for instance, in the question of the precipitation and re-solution of fine suspensions; likewise biological chemistry, in the precipitation and consolidation of calcium carbonate, ferric oxide, and other products associated with organisms.

Chemical questions allied to those of weathering will enter into the problems of the consolidation and alteration of sedimentary rocks, including cementation and recrystallization, the formation of low-temperature veins, silicification, and the growth of concretions. The elastic constants of porous aggregates offer an example of the physical data that are likely to be needed in this same connection.

Pyroclastic rocks.—The question of the origin of these rocks brings up the problem of explosive volcanism. In its larger aspects this belongs properly to the Section of Volcanology,¹ but the products of this type of volcanic activity are very widespread, and the particular physical and chemical questions arising from the state of subdivision and modes of distribution and alteration of the products deserve

¹ Of the American Geophysical Union.

special mention in this rather rough grouping of geophysical-chemical problems. Examples are: the molecular mechanism of the explosion, the peculiar properties of flowing dust-clouds, the physics of the projection of volcanic bombs, the sorting of products by air currents, and the weathering of "ash" to form colloidal products.

The metamorphic rocks.—The point where a rock ceases to be "igneous" or "sedimentary" and becomes "metamorphic" is not now exactly defined, though subject to exact definition, but a distinct set of physical and chemical questions undoubtedly enters into the problems of dynamic and thermal metamorphism. The effects of *non-uniform* pressure in causing the flowing of crystalline substances and aggregates and their solution and redeposition, as well as the forces exerted in their recrystallization, are of particular interest. The structures resulting from movement in silicate rocks under differential pressure are in need of quantitative study. Transfers of mechanical energy and its conversion into heat are also involved. Consolidation and recrystallization as a direct result of *uniform* pressure are likewise to be considered.

Mention should be made in this connection of the physics and chemistry involved in faulting as well as in jointing and minor movements of the solid rocks. These phenomena have often been treated under the principles of elastic theory as applied to homogeneous bodies, yet there can be no question that the elastic properties and conditions of rupture of aggregates must differ in many essential particulars from those of homogeneous bodies. Here is a considerable field for experimentation.

Bodies of water and the "chemical sediments".—The chemistry of the deposition of salts from sea water has already been made the subject of special research, and van't Hoff's results in this field are already familiar. The deposition of calcium carbonate awaits a similar thorough study. Allied questions are the formation of dolomite, the deposition of various salts from inclosed bodies of water, the deposition of phosphate rocks, the precipitation of colloidal suspensions of clay and other substances, and the origin of the great deposits of sedimentary iron ore.

Problems of fresh-water bodies and streams include the chemistry of bog-iron ores, and the amounts of insoluble and colloidal solids and of soluble salts carried by streams. Problems relating to underground waters may also be included here, such as: the dissolving and recrystallizing activity of underground waters; connate waters and their possible chemical changes; movements of underground waters and their relation to the alteration and concentration of gas and oil; principles of hydraulics governing the flow of wells and springs; and the characters which will serve to differentiate between vadose and juvenile waters.

The atmosphere.—The physics and chemistry of the atmosphere considered as a chemical unit or aggregate, while logically a part of geophysics and geochemistry, are usually considered to be part of the province of meteorology; and in fact most of the investigations in this field are being made by meteorologists or physicists employed in meteorological organizations. These questions will therefore not be further considered here. Data bearing on the origin of the earth's atmosphere and its possible changes of composition in the past—for example, the composition of the gases found in rocks and the gases dissolved by the waters of the oceans—are, however, of direct interest to the present Section.

LARGER UNITS.

The larger units of matter at the earth's surface are for the most part covered by other Sections of the American Geophysical Union. The atmosphere as a unit is treated by the Section of Meteorology and the atmospheric-electric branch of the Section of Terrestrial Magnetism and Electricity; the oceans by the Section of Physical Oceanography; the large land masses by the Section of Geodesy; volcanoes as units by the Section of Volcanology.

The larger geologic units (for example, petrographic provinces) and the rocks, considered as geologic units, might be considered to fall within the province of geology rather than geophysics, and the same may be said of the earth's glaciers and ice sheets.

There are certain problems connected with these larger units, however, that may be neglected by the Sections mentioned, not from any lack of appreciation of the importance of the problems, but solely by reason of lack of training and lack of acquaintance on the part of their personnel with the technique involved; just as some of the geophysical-chemical problems mentioned above may be, relatively, neglected by reason of the geophysical chemist's lack of training in other branches. For example, the physics of the flow of a glacier, considered as a unit, is not likely to be adequately handled by those trained only in the methods of glacial field geology, and it very properly becomes a subject for research under the present Section. The question of the chemical composition of a particular stratum of the atmosphere and the chemical equilibrium obtaining therein, while of great importance to the meteorologist, might fail of adequate treatment by an organization numbering no chemist on its staff. The distribution of certain rock-forming oxides according to "petrographic provinces" may be of primary interest to the geologist, yet the physico-chemical basis for that distribution—the question whether it represents an "original heterogeneity" or result of differentiation—is a problem for this Section. The flow of rock aggregates of varying composition, again a matter of

geological interest through being concerned in the processes of mountain-building, is a problem for the geophysicist. These examples will serve to indicate that there may be many points in which the Section of Geophysical-chemistry may be of direct assistance, through researches of its own type, in the work of other Sections.

B. PROPERTIES OF MATERIALS IN THE INTERIOR OF THE EARTH.

The late G. K. Gilbert has made apt reference² to the earth's interior in these words: "Once it contained the forges of blacksmith gods; or it was the birthplace of our race, or the home or prison of disembodied spirits * * *. Science now claims exclusive title but holds it chiefly for speculative purposes." Upon the Section of Geophysical-chemistry more than upon any other will fall the duty of maintaining the validity of the title while bringing the property into productive use.

The outstanding difference of condition to which substances in the earth's interior are subjected, as contrasted with substances at the surface, is the tremendous difference in hydrostatic pressure. Research on the properties of substances under high pressure is thus of first importance in relation to the interior of the earth. While we cannot at present go experimentally much beyond 12,000 megabars, a pressure corresponding to about 45 kilometers (about 29 miles of depth), yet a really adequate knowledge of properties in this range would give us an insight into the conditions in the interior beside which our present knowledge is equivalent to almost total ignorance.

It is most important to know in this connection the compressibility of the substances concerned, at various temperatures, and in both the liquid and the crystalline state, with its dependent constants such as change of melting point with pressure, and effect of pressure upon solubility. Other important data are: The existence of new polymorphic forms of substances; the effect of pressure upon rigidity and its related elastic moduli; the effect of pressure upon diathermancy, thermal conductivity, specific heat capacity, and magnetic susceptibility; and the effect of pressure in modifying equilibrium in homogeneous as well as heterogeneous systems.

The properties mentioned in the preceding paragraph are all properties of substances in equilibrium. The effect of pressure upon rates of reaction and rates of diffusion and crystallization are also of importance. If the planetesimal hypothesis of the origin of the earth, or some modification of it, is true, it is possible that the interior is very far from a state of chemical equilibrium, and that redistribution of matter and energy may be going forward ac-

²U. S. Geol. Survey Prof. Paper 85C, 1913 (35).

tively, with what results—whether rising or falling average temperature, increasing or decreasing volume, etc.—it is impossible now to say.

The preceding considerations apply also to the larger units of structure of the interior—although what these units may be we can only guess—and also to the earth itself as a unit. Complex mathematical analysis is necessary in applying the data to the units of structure as well as to the whole of a body as large as the earth, where the force of gravitation is itself variable with depth. These applications can in many cases be best made by those familiar with the properties in question as measured in the laboratory. The course of earthquake waves, to take an example of interest to the Section of Seismology, is dependent both upon the elastic constants of the earth's materials and the possible reflection and refraction of waves at the boundaries of internal structural features.

In this connection, the members of this Section could do a service to the other Sections by making clearer the real meaning of some of the physical concepts and physical constants involved in geophysical problems. For instance, much confusion has been caused by the fact that there is more than one kind of "rigidity." The geologist to whom the statement that "the earth has the rigidity of steel" is rather vague may take temporary comfort from the fact that the statement also needs much qualification and explanation to the physicist.³

General geophysics.—The physics of the earth considered as a unit (the classical "geophysics") is for the most part either covered by other Sections of the Geophysical Union or is customarily considered as a part of geology. Certain phases of geophysics, however, are not thus assignable and may be mentioned here in order that all of the groups of problems of the science may receive attention in this assembly of surveys.

The form and gravitation relations of our suspended spheroid, its magnetic and electrical properties, its properties as a vibrating body, and the physics of its air and water envelopes, are the obvious fields of appropriate Sections. Hypotheses of its origin and the logical deductions therefrom may confidently be left to the geologists, among whose faults that of narrow-mindedness and lack of a broad outlook in time and space have seldom been numbered.⁴ Its properties as an absorbing and reflecting body for external radiation are being well handled by the astrophysicists and meteorologists.

³ See Lambert, Journ. Wash. Acad. Sci., 10, 1920 (122-143).

⁴ In this connection it is important that the study of the composition and probable sources of the matter now being received by the earth, in the form of stony and metallic meteorites, be continued and extended.

The problem of the earth as a body radiating its own heat into space, however, is an example of a problem that may fail of treatment as a unit problem by any one of the above-mentioned groups acting alone. We are dealing not with a solid homogeneous spheroid of uniform surface temperature radiating freely into space, but with a rather heterogeneous body blanketed with several kinds of heat insulators whose composition varies both with depth and with time. Factors in the problem are: the production of heat by shrinkage; the contributions of heat from radioactive sources; the earth's present thermal conductivity and thermal gradient; the effect of varying carbon dioxide, water, ozone, inorganic dust, and clouds, upon the heat loss; and the effects of the possibly very different atmospheres with which the earth has been blanketed in past ages. The temperature at a given time and at a given distance from the center, as for instance at the solid surface of the land, depends upon a complex set of factors, and may well have been periodic in its variations.

The earth's volume and shape may have been similarly variable. In addition to the variation of temperature, already mentioned, the following are among the factors to be considered: the tides in the solid earth (on which extensive experimental work has recently been in progress) and the earth's properties as an elastic body; the viscosity of the earth as a whole, with relation to long-continued forces, and the existing state and method of maintenance of isostatic equilibrium in its surface layer; its breaking strength and form of rupture under forces changing too rapidly to cause flow; and the lag of elastic and viscous responses to changing forces, as in the case of the addition or removal of continental ice sheets.

Limitations of space forbid more than a sketchy outline of the problems set before the Section of Geophysical-chemistry, but it is hoped that the outline may have been sufficient to indicate the very fundamental character of those problems.

THE YIELDING OF THE EARTH'S CRUST.¹

By WILLIAM BOWIE,

Chief, Division of Geodesy, U. S. Coast and Geodetic Survey.

The geological evidence is such as to justify anyone in concluding that the material of at least the outer portion of the earth has moved from place to place during past geological periods. Material that must have been laid down in the form of sediments in shallow oceanic waters, as is evidenced by the presence of sea-shell fossils, is now above sea level, in some cases to the extent of many thousands of feet. Sedimentary rocks, which must have been laid down in horizontal or nearly horizontal strata, are now much curved and distorted. There could be cited many cases to show that strata have not only moved in elevation but also horizontally. What has caused these movements is one of the outstanding problems in geophysics and geology.

To the superficial view, erosion of a mountain region and consequent sedimentation of a river delta present nothing but a tendency to smooth out the earth by cutting down its elevations to fill up its hollows. In short, the matter may appear as simple as the operation of a steam shovel and a line of carts grading a new city section. Comparatively recent geodetic investigations referred to in what follows lead us, however, to regard the matter as much more complex. Even yet a great deal more evidence is required, but there seems to be reason to think that the secondary consequences of erosion and sedimentation are most far-reaching and significant, leading to profound modification of the views of mountain building which formerly prevailed.

ISOSTASY AND ISOSTATIC COMPENSATION.

During the last half of the nineteenth century scientists dealing with geodetic and geological problems advanced the idea that land masses were higher in elevation than the bottoms of the oceans because of lighter material under the former than under the latter.

¹ Paper delivered at meeting of Philosophical Society of Washington, Mar. 11, 1922.

This balancing of the earth's crust was termed by C. E. Dutton, isostasy, or equal pressure. The early writers on the subject of isostasy developed the qualitative side of the theory, but it was only during the past 30 years that any quantitative values were made available.² John F. Hayford, as chief of the Division of Geodesy of the U. S. Coast and Geodetic Survey, conducted a very elaborate investigation which showed that blocks of the earth's crust, of the same cross section at their bases, were in equilibrium; that is, that each block had the same mass as any other block of the crust. The base of each of these blocks was assumed to be at a definite depth below sea level, which depth was termed the depth of compensation. The compensation is defined as the deficiency of mass in the block under any particular area and exactly balances the mass which appears at the top of the block above sea level. It is also the excess in mass in a block under an ocean, and in this case it exactly offsets or balances the deficiency of material in the space occupied by the water of the ocean above the block.

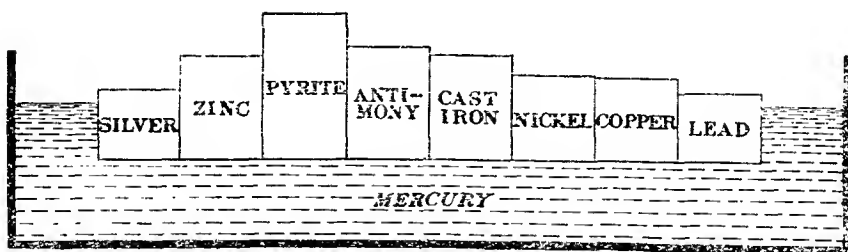


FIG. 1.—A simple case of isostatic equilibrium.

If equal masses of different metals, each lighter than mercury, are moulded to the same cross section they will sink to the same depth when placed in mercury. Their lower surfaces will form a plane while their upper surfaces will be irregular. There will be equal pressure at the base of the different blocks. This is isostatic equilibrium in its simplest form.

The results of the investigations of Hayford were reported in two publications³ of the U. S. Coast and Geodetic Survey. The investigations started by Hayford have been continued by the U. S. Coast and Geodetic Survey up to the present time. Later results⁴ have

² The earliest attempt to prove the theory of isostasy was made by G. R. Putnam. (See Report U. S. Coast and Geodetic Survey for 1894, pt. 2, app. 1. Relative determinations of gravity with half-second pendulums, and other pendulum investigations.)

³ The figure of the earth and isostasy from measurements in the United States, by John F. Hayford.

Supplemental investigations in 1909 of the figure of the earth and isostasy, by John F. Hayford.

⁴ Effect of topography and isostatic compensation on the intensity of gravity. U. S. Coast and Geodetic Survey Special Publication No. 10, by John F. Hayford and William Bowie.

Same, U. S. Coast and Geodetic Survey Special Publication No. 12, by William Bowie. Investigations of gravity and isostasy, U. S. Coast and Geodetic Survey Special Publication No. 40, by William Bowie.

dealt especially with the relation between the theory of isostasy and the value of the intensity of gravity.

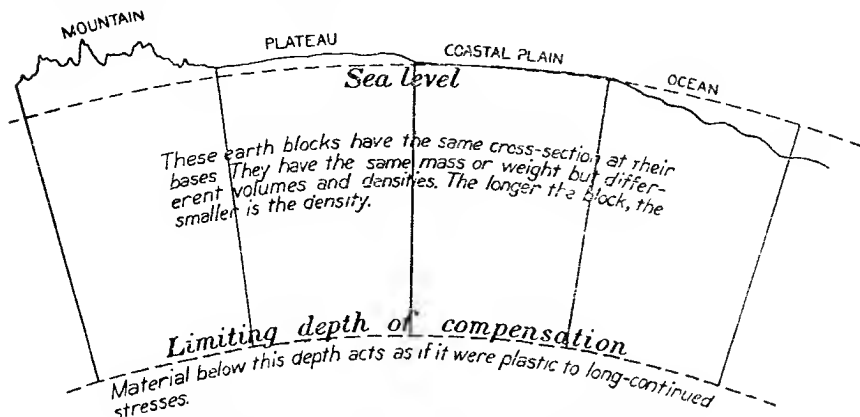


FIG. 2.—Isostatic equilibrium in the earth's crust.

The isostatic investigations show that blocks of the earth's crust of different lengths have the same mass; therefore the pressure of the blocks at a certain distance below sea level where the material changes from a resisting to a yielding solid will be the same throughout. The longer blocks are composed of less dense material than the shorter ones.

While it is impossible to determine definitely the depth within which the isostatic compensation occurs, the investigations have

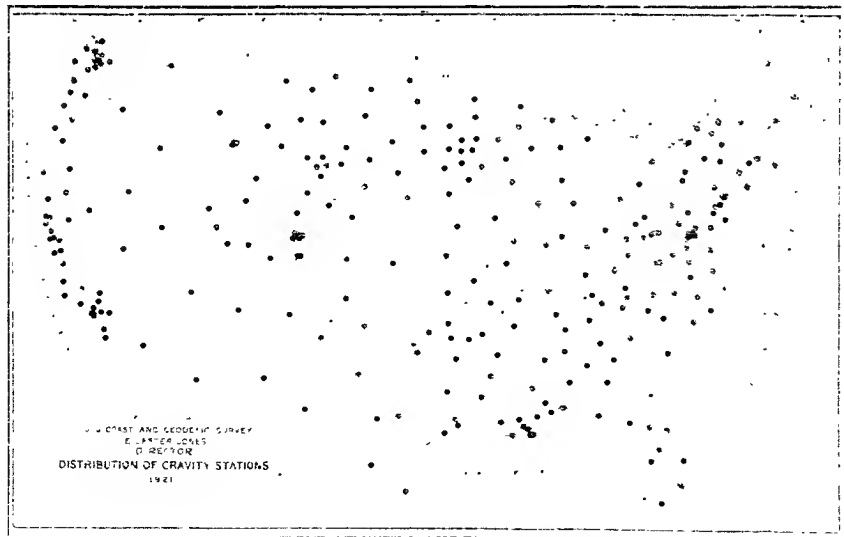


FIG. 3.—Gravity stations in the United States.

There are now 286 gravity stations in the United States, located as shown on the diagram. The values of gravity are used in the isostatic investigation.

shown that the depth is of the order of magnitude of 60 miles. At or just below that depth the material of the earth is assumed to change from a solid which resists stresses acting in a horizontal direction to one which will yield plastically to those stresses.

It has been found that there is no difference in the isostatic condition from one place on the earth to another, nor is there any difference in this condition between blocks under elevated areas and those of little or no elevation. In other words, the isostatic condition is entirely universal, and what may be called the isostatic gravity anomalies, or the difference between observed and computed values of gravity, and the isostatic deflections of the vertical show no relation whatever to the elevation of the ground on which the various values of gravity or deflections of the vertical may be determined.

Since we find all blocks of the earth's crust in equilibrium now, it appears certain that a like equilibrium existed in past geological ages or periods. If this be true, as it seems most reasonable to assume, we must change considerably some of our ideas as to the causes of the yielding of the material of the earth's crust and also change our views as to the direction in which much of this yielding has occurred.

EROSION AND SEDIMENTATION IN LIGHT OF ISOSTASY.

All elevated areas are continually losing material from the action of water and air. This material is carried by these elements down to regions which are lower. A mountain system loses material in vast quantities which is transported by streams and rivers to the valleys and the edges of the ocean. Undoubtedly, the isostatic balance of the blocks of the earth's crust is disturbed by this transfer of material. The block from which material is being eroded will become lighter than normal, and the block on which the sediments are placed will become heavier. It is practically certain that, as a result of this disturbance of the balance, the earth's crust yields under the sedimentary area, causing a downwarping and an outflow of material at the bottom of the sedimentary block towards blocks from which material has been eroded. The effect of the horizontal surface movement towards the sedimentary area will result in other material entering at the bottom of the block from which material is eroded. The addition of this material to the bottom of the eroded columns results in a rising of that column.

As a consequence of the transfer of material at the surface of the earth, there is a sinking of one block, the rising of another, and a horizontal sub-crustal transfer of material from the first towards the second.

We can thus see that there is a tendency for any area to be maintained in its elevation by the isostatic adjustment. There would be no change in the elevation of the surface, as a result of the transfer

of material and the isostatic adjustment, if the material eroded and deposited were of the same density as the material which moves horizontally below the depth of compensation, but undoubtedly there is a decided difference between the density of the material below the depth of compensation and that which is eroded and deposited at the surface. It appears reasonable to suppose that the deep material is at least ten per cent denser than the material at the surface. If this is the case, a different volume of material is transferred from sedimentary to erosion blocks below the earth's crust from that which is moved over the earth's surface in the opposite

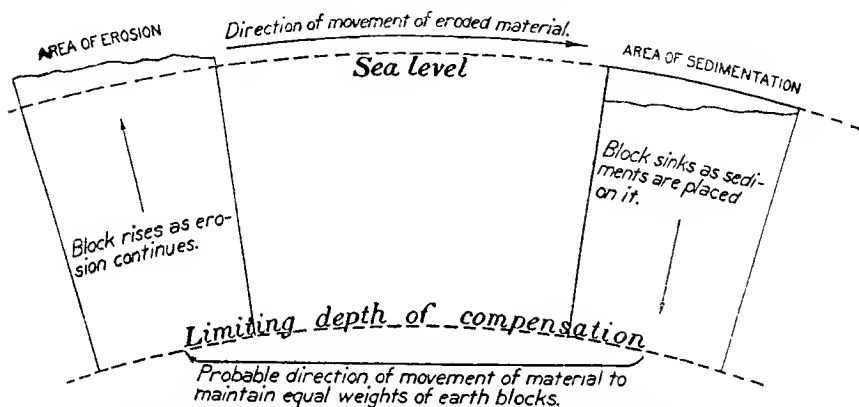


FIG. 4.—Movements in the earth's crust incident to isostatic adjustment.

As material is eroded from a high area and carried over the surface of the earth to a lower one and deposited as sediment, the earth block under the sediment sinks deeper into the earth. This causes a deep-seated horizontal movement of material from the sedimentary block towards the erosion block. Material enters the bottom of the erosion block to maintain the isostatic equilibrium, thus forcing up the material of the block under the area of erosion. The arrows show the direction of the movement.

direction. The result of this difference is to lower gradually the surface of the blocks that are undergoing erosion. If 1,000 feet of material is eroded from an area, the thickness of the mass of material that will come into the bottom of the block, as a result of the isostatic adjustment, will be only 900 feet, thus lowering the height of the block by 100 feet. In order to lower the surface of a mountain system by 3,000 feet, on an average, it is necessary that approximately 30,000 feet be eroded from its area.

It may be said that, while the theory of isostasy does not account for the creation of mountain systems, it apparently does account for the gradual lowering of a mountain system. The lowering of a mountain system to the point at which erosion ceases is termed base-leveling or peneplanation. It is evident that there must be a decided slope to any ground to permit the streams and rivers to transport material. As the lighter material of the mountain area is eroded from the surface and an equal mass but smaller volume of material

is brought into the base of the block under the mountain area, in order to restore the isostatic equilibrium, the length of the block will gradually diminish and the area will cease to be different in its elevation from the surrounding region.

MOUNTAIN SYSTEMS NOT CAUSED BY SIDE THRUSTS.

As there is to-day an isostatic balancing of the blocks of the earth's crust under various classes of topography (that is, different degrees of elevation), and as it is reasonable to assume that this balance has obtained in past geological periods, we have to conclude that moun-

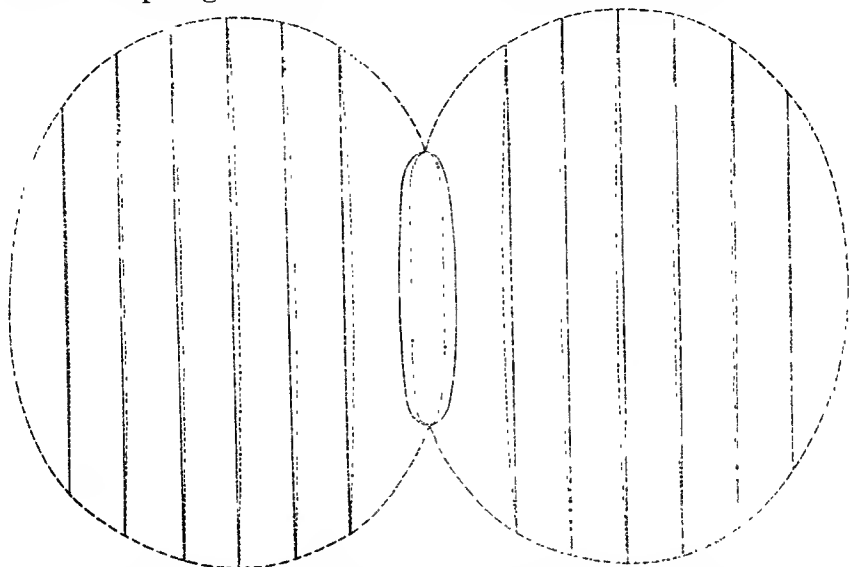


FIG. 5.—Distortion of crust incident to mountain formation by horizontal thrust.

This diagram indicates graphically the distortion that would take place in the earth's crust if the uplift of a mountain area were due entirely to horizontal thrusts of a regional nature. The central oval in a full line represents the mountain area—about 200 miles wide and 1,000 miles long. The full straight lines represent imaginary lines approximately 200 miles apart, placed on the earth's surface before movement began. The dotted lines indicate positions of full lines after uplift. The material of the earth's crust which is supposed by some to carry thrusts competent to raise a mountain mass must be so yielding as to undergo the distortions indicated. Instead of the earth's crust being contracted in a horizontal direction from the thrusts it would actually be expanded.

tain systems are not due to horizontal movements of the crust resulting from forces acting in a horizontal direction from great distances away from the affected regions. Should there be such horizontal movements, we would be forced to believe that extra loads were placed on blocks which were previously in isostatic equilibrium. We do not have blocks that depart materially from the isostatic equilibrium, and therefore we must eliminate horizontal forces of a regional nature as the cause of the uplift of a mountain system.

If we eliminate the horizontal thrust theory of the formation of mountain systems, we must adopt the vertical movement theory. The

first step in the latter is to attempt to find a cause of the vertical movement of material of the earth's crust which is local in its character.

CAUSES TENDING TO THE UPLIFT OF MOUNTAINS AND TO THE BRINGING ABOUT OF SUBSIDENCE.

By a process of elimination we conclude that the uplift of the mountain system must be due to an actual decrease in the density of the material forming the blocks under the affected area. In order that the isostatic balance may be maintained the density under a mountain area must be less, on an average, than the density which obtains in a block whose surface is at or close to sea level. But the mountain area was once an area of sedimentation as is shown by the character of its rocks. How, then, could the block under this moun-

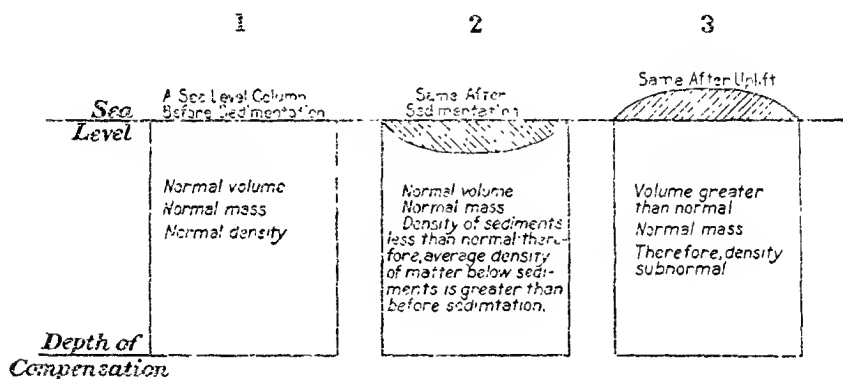


FIG. 6.—Changes in densities in the earth's crust.

A block, with its surface at sea level, that is in isostatic equilibrium, must have an increase in the density of its original material after heavy sedimentation. It must have a lighter density than normal after its surface has been uplifted.

tain area have become longer, to the extent say of two miles, and still be in isostatic equilibrium without there having been an actual decrease in the density of the material of the column? Apparently a decrease in density must have occurred.

We must now go one step further and inquire as to what could have caused the change in density from normal to subnormal. Let it be assumed that the material of the earth's crust is composed of horizontal layers. When an area is undergoing sedimentation the layers of the block under the sediments are being forced down into regions which are undoubtedly hotter than those they occupied prior to the deposition of material at the surface of the block. It is not known definitely or accurately what is the temperature gradient even for the first 5,000 or 10,000 feet of the earth's material for it varies from place to place. As a working hypothesis, however, we

are fairly safe in assuming that the change in temperature for the first mile of the earth's crust is about 50°C . If in any particular area we have sediments laid down to a depth of 6 miles, and this is not beyond the probable depth, and if the temperature gradient is the same for the whole depth of the block, then there would be a change in the temperature of the material of approximately 300°C . It is reasonably certain that as the block is lowered, as sediments are placed on it, the material will not increase its temperature as rapidly as it subsides. There undoubtedly will be a very great lag in the temperature and it will be a long time after the deposition of sediments has ceased that the temperature of the column will become normal—that is, that the geoisotherms will rise within the lowered block to their normal depths below sea level. As a result of the increase in the temperature there will be a thermal expansion

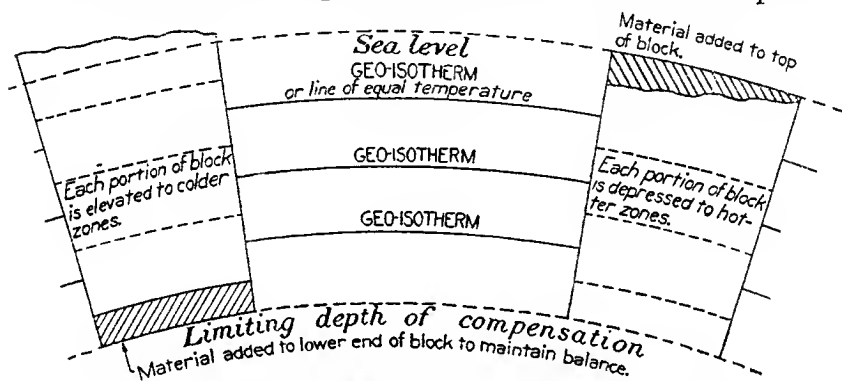


FIG. 7.—Displacement of geoisotherms due to isostatic adjustment.

As sediments are placed on a block of the earth's crust the block is depressed and each of its elements goes to a zone which is hotter than the one it originally occupied. As erosion takes place the block of the crust under the erosion area is lightened, thus causing material to enter the lower end of the block. Each element of the block will be forced up into a zone that is colder than the one that it previously occupied. The geoisotherms are depressed in the block under the sedimentary area and are elevated in the block under the erosion area.

of the block which may amount to as much as 3,000 feet. The surface of the block will be raised approximately that amount, but this is an elevation far less than we find existing in most mountain systems and, therefore, we have to find some additional process to cause the uplift. It can not be proved, of course, that the other cause is a physical or chemical action taking place in the column as a result of the increase in temperature, but this seems to be the only thing left which could assist the thermal expansion in decreasing the densities of the block and extending its length from about 60 to 62 miles. An expansion of about 3 per cent is necessary to raise a sedimentary area to an elevation of 2 miles.

After a mountain area has been base-leveled, that is, reduced in elevation to such a point that erosion ceases, a downwarping is the

next stage in its geological history. This downwarping undoubtedly must be due to an increase in the density of the material of the block of the earth's crust under the area, which results in a shortening of the block and, consequently, in a lowering of the surface. We are forced to this conclusion because otherwise there would be a change in the mass of the blocks upsetting the isostatic equilibrium at its base. The results of the geodetic investigation indicate very clearly that the blocks are in approximate equilibrium and that the deviation from the perfect state of equilibrium is very small.

The contraction of the column and the increase in the density of its material probably is due to a process which is just the reverse of the one which causes the expansion of a column resulting in the uplift of mountains.

While an elevated area is being eroded, the column under it is continually rising, because of the material which enters at the lower end of the column or block. This material is moved into the block by what is called the isostatic adjustment. Since the surface of a block that is undergoing erosion is lowered by only about one-tenth of the thickness of the matter which is eroded, there must be tens of thousands of feet of material carried away before the surface of the block is base-leveled.

Let it be assumed that 30,000 feet of matter have been eroded from a certain elevated region. Then the layers of material of the block under the area have been elevated by an amount approximately nine-tenths of the thickness of the eroded material; that is, each layer of the block will have been brought closer to the surface of the earth by that amount. As a result of this uplift of material of the block under the mountain area, each layer will be raised to a zone which is colder by an amount equal to the change in temperature from the zone previously occupied to its subsequent location. If the vertical movement has been five miles and should the temperature gradient be about 50° C. per mile, then the material of each layer will have its temperature decreased by about 250° C. This change in temperature, however, will probably occur at a much slower rate than the rate of uplift of the material of the block during the erosion. When the material finally assumes the new and much lower temperature it will have undergone a thermal contraction, but this thermal contraction cannot lower the surface more than about 2,500 feet. There must occur an additional increase in density and shortening of the column from some physical or chemical process.

This process must be started by the lowering of the temperature of the material throughout the column, and it continues during the entire period of the subsequent sedimentation. This seems to be a logical assumption in view of the conditions existing in a sedimen-

tary area. Since the material which flows horizontally from the lower end of the block to maintain equilibrium is heavier than the sediments which are laid down on its surface, there will be a less volume of material removed from the block than is brought to it in the form of sediments, and therefore the surface should apparently be gradually increased in elevation. There must be a continuous contraction of the material of the block in order that there can be a continuous deposition of material at or very near sea level. This would lead one to believe that the loss of heat continues after the former mountain area has been depressed to sea level and during the process of sedimentation of the area.

There are two other causes of downwarping, but they are secondary and not primary or fundamental. One is the weight of the sediments which causes the original material of the block to sink lower into the earth. The other is the compression of the material of the block due to the weight of the sediments.

The contraction of the original material of the column must be due in greater part to the chemical or physical changes which must have occurred as a result of the loss of much heat after the area had become base-leveled. It will be seen from the above that the phenomenon of downwarping of an area is rather complicated and it is impossible to estimate the influence of each of the several causes.

CYCLES OF UPLIFT AND SUBSIDENCE.

It seems probable that there is a cycle of erosion and deposition in any particular region of the earth which causes a portion of the region to be at or below sea level at one time and much elevated at another, and that these two conditions might occur a number of times in the same general area. The area which is now high and subject to erosion may later be the region within which new sediments will be placed, and the region now undergoing sedimentation may, and probably will, be one of uplift in the future. There are numerous examples of mountain areas which have been below sea level several times, as shown by the presence of sedimentary rocks of different geological ages. This change in the elevation of the surface of the block is apparently due to local causes and has no relation to the supposed horizontal stresses resulting from a shrinking of the earth's nucleus which, it has been believed, caused the uplift of mountain systems as wrinkles of the earth's crust.

The system outlined above, consisting of the erosion and sedimentary cycles, seems to be a simple one, and there are reasons for feeling that the causes are competent ones. At least, there is something tangible to work with, while, with the old theory of the horizontal thrusts due to shrinkage of the nucleus of the earth, it is difficult to conceive how the forces acted.

There have been great horizontal movements of material in areas of uplift, but these seem to be confined to strata of very moderate thickness, especially as compared with the thickness of the earth's crust. These movements were very probably incidental to the vertical movement which caused the uplift and maintained the isostatic balance of the blocks. Or the horizontal movements may have been partly due to distortion and rupture of strata incidental to the giving way or yielding of the earth's crust under sedimentary loads. The amount of material involved in the horizontal movements at the surface, which are undoubtedly local in character, is small as compared with that involved in the horizontal movement which takes place below the earth's crust to maintain the isostatic equilibrium.

THE DEPTH OF ISOSTATIC ADJUSTMENT.

It is a debatable question as to the depth at which the isostatic adjustment takes place; that is, the depth at which the horizontal movements occur. If we should draw a diagram showing the stress differences at various depths below sea level which must obtain between a block under an elevated area and a block whose surface is at or close to sea level, we should find that the stress difference would be directed from the elevated block toward the other one until the depth of compensation is reached. Now, if there should be some erosion of even a small amount of material from the elevated block and a corresponding deposition on the lower one, the stress difference would still be in the same direction for the upper part of the blocks but would be in the opposite direction or from the low block toward the elevated block near their lower ends. A diagram, showing these stress differences, indicates that there can be no transfer of material horizontally from the area of sedimentation back toward the area of erosion within the first few miles of the earth's surface. Undoubtedly, the transference can not be much above the depth of compensation, and is probably below.

It is not known whether the horizontal movements of the material to maintain the isostatic balance take place near the depth of compensation or whether it is lower down in the earth. This is a matter that is of small moment, geologically or otherwise. The principal problem is to locate approximately the depth at which the material changes from one which resists horizontal movements due to stress differences to one which is yielding to such stresses. It is somewhat uncertain as to whether or not the depth of compensation is actually the boundary between the resisting matter and the matter that is yielding. It is certain that no compensation can be located below the resisting material, but it is possible for the compensation to occur in the upper part of the block of resisting matter, and

therefore, the deduction of the depth of compensation from the geodetic data may give us a value that is somewhat smaller than the depth at which the material changes from one of resistance to one of yielding. The method by which the depth of compensation is derived is a sort of evening-up process, and, therefore, it is practically certain that the depth of compensation is somewhat above the depth or zone at which the change in character of the material takes place.

It is possible, and in fact probable, that the depth at which the material changes from one of resistance to one of yielding is not

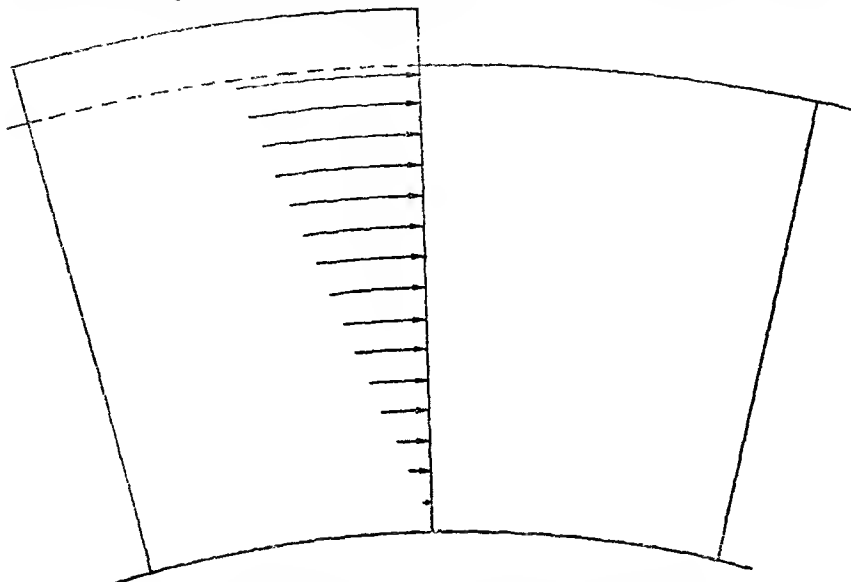


FIG. 8.—Stress diagram of two columns in isostatic equilibrium.

A diagram of stress differences between two blocks of the earth's crust of different elevations indicates that the tendency of the material to move horizontally is in the direction from the elevated block toward the lower one. This is on the assumption that the two blocks are in isostatic equilibrium.

very different in different parts of the earth. Such a change must be the result of a change in temperature. The pressure naturally is approximately the same at all places at a certain depth below sea level, due to the isostatic equilibrium. It appears very probable that the temperature gradient is approximately the same in different blocks of the earth's crust. The composition of the material of the crust is approximately the same, or it is safe to assume that this is the case, and, therefore, in no one place would the material at a certain depth be much more resistant or yielding than the material at the same depth at some other place. It seems, therefore, that so long as the change from material that is resistant to one

that is yielding to horizontal stresses is a function merely of the temperature, and as the temperature at any particular depth is no doubt somewhat uniform around the whole earth, the depth of transition from resisting to yielding material can not be very different for different blocks of the earth's crust, except where the geotherms are displaced under areas of active erosion and of active

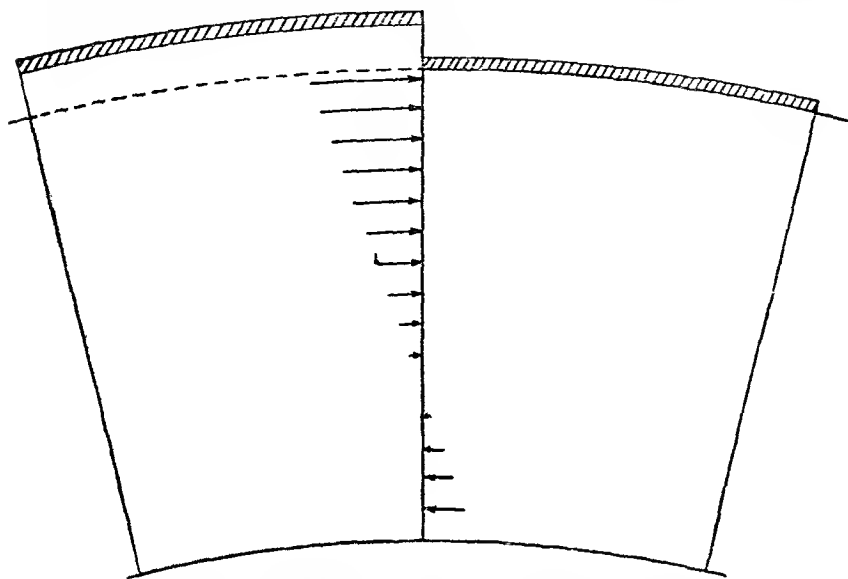


FIG. 9.—Stress diagram of columns after erosion and deposition.

After the erosion of material from a high block and its deposition on a lower one, the stress differences will be from the high block toward the low one almost down to the depth of compensation. The stress differences near the lower ends of the blocks are from the low block toward the high one. This is on the assumption that the isostatic adjustment has not yet taken place to counterbalance the transfer of material at the surface.

sedimentation due to comparatively rapid vertical movements of the material of the blocks.

THE EARTH IS A YIELDING BODY.

Since the material of the earth is yielding to vertical forces and since the material below the earth's crust moves horizontally to restore the isostatic balance, it is appropriate to use the words of Professor Hayford and call the earth a "failing structure." I prefer to call it a *yielding body*. The material of the crust and that just below it must give way to comparatively small stress differences.

THE AGE OF THE EARTH.¹

By the Right Hon. LORD RAYLEIGH, F. R. S., and Others.

The subject which we have met to consider to-day is enumbered with past controversy. It can not be denied, I am afraid, that exponents of partienlar views in the past have laid too much emphasis on their own partienlar way of looking at the problem without making enough allowance for human fallibility. I shall try, so far as possible, to avoid this pitfall. There has been a tendency on all sides for specialists in one branch of science to consider themselves free to disregard evidence drawn from a class of considerations with which they are not familiar. I am sure that this is not the road to truth. In attempting a problem of this kind, when we seek to plumb into the depths of time, far beyond human experience, we can not afford to neglect evidence drawn from any quarter, even if it is not the kind of evidence which we find it most congenial to contemplate. A parallel case is that of a jury of plain men in a murder trial. They may know nothing of medical jurisprudence, post-mortem examinations, and so on. They may even consider the subject repellent; but that does not exempt them from the duty of fully considering and weighing such evidence to the best of their ability. The witnesses in the trial have, however, to limit themselves to matters with which they are personally conversant. I will try to give my evidence within these limits.

The phrase "age of the earth," though rather vague, is perhaps definite enough for our purpose. What we want to know is, how long has the earth's surface been fitted for the habitation of living beings; or, alternatively, how long has it taken to accumulate the known series of geological formations? These questions are not the same, but I do not think that we shall need to insist on the distinction this morning.

Lord Kelvin's arguments depended on attempts to limit the length of time during which the earth's surface temperature could have re-

¹ Contributions to a joint discussion of the Sections of Mathematical and Physical Science, Geology, Zoology, and Botany of the British Association at Edinburgh on Sept. 13, 1921. Reprinted by permission from *Nature*, Oct. 27, 1921.

mained substantially the same as at present, and he attacked this problem from two different points of view. In the first place he attempted to set a limit of time to the duration of the sun's heat; and secondly, from consideration of the earth's internal heat, he argued back to the time when the surface was too hot for the presence of living beings. I have heard a suggestion that there is some mutual inconsistency in these two lines of argument—consideration of the sun's heat makes the past temperature too low; consideration of the earth's heat makes it too high—but I do not think that this criticism is more than superficially plausible. The point was rather that from either of these arguments a condition widely different from the present would be reached, and therefore that, even if there were some unrecognized flaw in one of the arguments, the other would stand. Possibly, looking back into the remote past, a condition of the earth's surface is imaginable where the mean temperature was much the same as at present, heat coming from the earth's interior in compensation for a diminished radiation from the sun, but I feel sure you will all agree with me that we can not get more time by special pleading of this kind. The fossiliferous rocks have, without doubt, been accumulated under conditions of solar radiation not essentially different from the present. One simple consideration is that the plants in the coal measures obviously had green leaves, and that these could not function without a full allowance of solar radiation.

We have then to consider whether Lord Kelvin's arguments can stand in the light of present knowledge. I think that we must admit that they can not.

First as regards the earth's heat, it is now generally known that the premises of Lord Kelvin's calculation, carefully particularized by him, are upset by the discovery of radio-active substances in the earth. In 1906 I made a determination of the amount of radium in the superficial parts of the earth which are alone accessible. From radium analysis we can calculate the amount of uranium and other associated substances and the thermal output from them, and the result is to show that if we suppose the same radium content to extend to a depth of some 20 miles, the whole output of heat would be accounted for without assuming that any of it comes from the store of primeval heat as postulated by Lord Kelvin. It is without doubt difficult to understand why the output of heat is not greater, for it would certainly be expected that the rocky crust of earth would be more than 20 miles thick, to say nothing of any radium there might be in the unknown interior.

Can we at present infer anything definite from the earth's internal heat as to the possible duration of geological time? I think practi-

cally not. It appears certain that the radioactive materials present in the earth are generating at least as much heat as is now leaking out from the earth into space. If they are generating more than this (and there is evidence to suggest that they are), the temperature must, according to all received views, be rising. In a word, we are puzzled to explain the existing state of things, and cannot use it as a firm basis from which to explore the past.

Next, as to the sun's heat. Lord Kelvin's argument was that we knew of no possible source at all adequate to supply the existing output of solar energy except secular contraction, and even this source of supply was not enough to account for more than 20,000,000 years of solar heat in the past. It is impossible to condemn on principle arguments of this kind. We often must, and do, rely on them in science as in everyday affairs; but a certain reserve is always needed on the ground that there are more things in heaven and earth than are dreamt of in our philosophy. Knowledge which has accumulated since Lord Kelvin's time has driven us back on this alternative.

The sun is only one of the host of stars, and if we find it impossible to account adequately for their radiation by contraction it evidently will not do to assume that the sun is limited to this source of supply.

Now, some of the stars (the giant red stars), though of about the same mass as the sun, are radiating energy at something like one thousand times the rate that the sun does. They ought, according to the contraction theory, to have expended a considerable fraction of their total energy in historical times. No one will maintain that this has occurred, and if not there must be some source of supply other than contraction. It is not necessary for our immediate purpose to inquire what this source is. It is enough to note that its existence invalidates Lord Kelvin's estimate of the age of the sun's heat.

Modern knowledge in radioactivity has given what appears, if separately considered, to be a firm and satisfactory basis for the estimation of geological time. Uranium, for example, goes through a series of changes (radium is one of the stages in its progress), changing eventually into an isotope of lead—that is, an element chemically indistinguishable from lead, except by a slight difference of atomic weight and (practically at least) inseparable from ordinary lead by chemical means if once mixed with it. The isotope of lead in question has probably an atomic weight of 206 exactly, as contrasted with an atomic weight of 207.1 for ordinary lead.² This is much less than the atomic weight of uranium (238.5), and the difference represents approximately the weight of helium atoms, which are the débris shed at the various stages of the transformation.

² Ordinary lead may partly consist of it, but this is not yet certain, and not very important for the immediate purpose.

Further, it is well established that a gram of uranium as found along with its products in rocks and minerals is now changing at a rate represented by the production of 1.88×10^{-11} grams of helium and 1.22×10^{-10} grams of lead isotope per annum. We have not time this morning to consider the methods by which these figures have been reached. It must suffice to say that in the case of helium it amounts practically to direct observation, while in the case of lead isotope the evidence, though less direct, is very strong, and, so far as I am aware, is not contested by any student of the subject. I have said that this is the rate at which one gram of uranium as found in the earth is producing helium and lead isotope at present. It is important to inquire whether one gram of uranium did the same in the past. This we can not, of course, determine directly. It is certain that nothing we can do in a laboratory in the way of change of temperature and pressure can alter the rate sensibly, and enough has been done in this way to make it unlikely that any pressures and temperatures encountered in the superficial parts of the earth could have such an effect. It has been suggested by Professor Joly that the absolute age of a gram of uranium may affect its rate of disintegration. All possibilities should be considered, but this suggestion derives no support from the behavior of the short-lived radioactive substances the behavior of which we can watch.

Upon the whole, therefore, it would seem that in the disintegration of a gram of uranium we have a process the rate of which can be relied upon to have been the same in the past as we now observe it to be.

The application is either to individual uranium minerals or to the earth's crust as a whole. Taking first the minerals containing uranium, these are found in all cases to contain helium and lead. The helium in them, which appears to be retained mechanically, may safely be treated as wholly a radioactive product. The lead in some cases conforms closely to the expected atomic weight of 206, about one unit lower than common lead, and in such cases we may safely regard the whole of it as a product of uranium disintegration.

Thus take the broggerite found in the pre-Cambrian rocks at Moss, Norway. The lead in this mineral has an atomic weight of 206.06 as determined by Hönigschmied and Fräulein St. Horovitz. The ratio of lead to uranium is 1:3. Taking the lead as all produced by uranium at the rate above given, we get an age of 925,000,000 years. Some minerals from other archæan rocks in Norway give a rather longer age.

In other cases there is some complication, owing to the fact that thorium is associated with uranium in the mineral and that it, too, produces helium and an isotope of lead of atomic weight probably 208 exactly, about one unit higher than common lead.

In a third class of cases the uranium mineral, pitchblende, occurs in a metalliferous vein, and the lead isotope produced in the mineral is diluted with common lead which entered into its original composition.

These various complications introduce a certain amount of difficulty and even ambiguity into the interpretation. A full discussion can not be given on an occasion like the present, but the complications can not, I think, be considered to modify the broad result.

A determination of the amount of helium in minerals gives an alternative method of estimating geological age; but helium, unlike lead, is liable to leak away, hence the estimate gives a minimum only. I have found in this way ages which, speaking generally, are about one-third of the values which estimations of lead have given, and are, therefore, generally confirmatory, having regard to leakage of helium.

The helium method is applicable in some cases to materials found in the younger formations, and proves that the ages even of these are to be reckoned in millions of years. Thus the helium in an Eocene iron ore indicated 30,000,000 years at least.

Returning now to the estimation of lead, H. N. Russell has recently applied this line of reasoning to the earth's crust as a whole. He takes the uranium in the earth as 7×10^{-6} of the whole, and the lead as 22×10^{-6} of the whole. It is necessary to remark that we do not know very definitely whether the lead distributed in the rocks in small proportion and very difficult of extraction is the same mixture of isotope as the lead of mineral veins. We call the latter "common lead," but nearly all the lead in the earth's crust is of the former kind.

Even if we did know that "rock lead" were the same as "vein lead," we should still not be in a position to say what fraction of it was uranium-lead, as we do not know whether an isotope having an atomic weight 207 exists. If it does, obviously the problem how much uranium-lead (atomic weight 206) and how much thorium-lead (atomic weight 208) exists in common lead (atomic weight 207) becomes indeterminate in the absence of further data. An analysis of lead by positive rays will probably soon become feasible, and with a determination of the atomic weight of "rock lead" will do much to clear up the matter.

If all the lead were uranium-lead, and had been generated since formation of the earth's crust, the time required would be 11×10^9 years. This is certainly too great. Allowing for the production of some of the lead from thorium, Russell finds a period of 8×10^9 years as the upper limit. This is about six times the age indicated by the oldest individual radio-active minerals that have been examined.

I have now traversed that part of our subject of which I feel competent to speak. The upshot is that radio-active methods of research indicate a moderate multiple of 1,000,000,000 years as the duration of the earth's crust as suitable for the habitation of living beings, and that no other considerations from the side of pure physics or astronomy afford any definite presumption against this estimate.

The arguments from geology and biology I must leave to our colleagues from other sections. May I venture to say that I for one consider the topics with which they will deal as not less interesting and important than those which it has been my privilege to try to lay before you.

By Prof. W. J. SOLLAS, F. R. S.

Huxley once sagely remarked that the zoologist must take his time from the geological clock. The geologist is thus charged with a great responsibility which he would willingly share with the physicist and astronomer. One of the earliest attempts to determine the age of the earth by purely geological means was made by the late Dr. Samuel Haughton, who based his calculations on the rate of deposition of sediment supposed to be evenly distributed over the whole floor of the ocean. This led to the conclusion that the time which must have elapsed since the first appearance of the dry land is of the same order of magnitude as that now presented for our consideration by Lord Rayleigh.

Soon, however, it was discovered, as a result of exploration by the *Challenger*, that deposition is limited to a comparatively narrow belt bordering the continents—a limitation due to several causes, chief among them the fact that sediment sinks much more rapidly in salt water than fresh. On taking account of this factor Haughton's period was reduced to about 100,000,000 years. At the same time a new method was devised by Professor Joly which depends on the rate at which sodium is supplied to the sea, and this led to a similar result.

Antecedent to these attempts, another method, based on the rate at which the earth is losing heat, had been employed by Lord Kelvin, and this gave at first an estimate concordant with the preceding—*i. e.*, 100,000,000 years. Later, however, this allowance was reduced to forty, or preferably to twenty, millions, and by the uncompromising Professor Tait to ten millions.

These estimates proved very embarrassing to the geologists, who found it impossible to compress the events of the earth's history into so restricted an interval without unduly "hurrying up the phenomena." Lord Kelvin, however, was inflexible and impressively asserted that he could conceive of no escape from his conclusions.

With the discovery of radioactive elements the inconceivable happened, and Lord Rayleigh was amongst the first to perceive that the rate of disintegration of uranium might be used to provide the geologist with a trustworthy timekeeper. By his experiments and reasoning he had not only enlarged our views on the duration of geological time, but also opened the way to other methods of investigation which in the hands of Professor Joly and Doctor Holmes have yielded concordant results.

The age of the earth was thus increased from a mere score of millions to a thousand millions and more, and the geologist who had before been bankrupt in time now found himself suddenly transformed into a capitalist with more millions in the bank than he knew how to dispose of.

The consequences have been far-reaching; already some geologists, thus newly enriched, chief among them the brilliant Barrell, whose loss we still deplore, have begun to rebuild their science on a new and magnificent scale, while more cautious people, like myself, too cautious, perhaps, are anxious first of all to make sure that the new clock is not as much too fast as Lord Kelvin's was too slow. Lord Rayleigh does not regard this as inconceivable, but as unlikely. Professor Joly, on the other hand, can not only conceive a source of error, but has obtained evidence which seems to show where it lies. This is furnished by a study of the well-known pleochroic haloes which surround minute uranium- or thorium-bearing crystals included in the black mica of granite. By a very elegant method of investigation he shows that these furnish estimates of geological time of the same order as those established by Lord Rayleigh and Doctor Holmes; but he does not stop there; he goes further. The haloes consist of a number (seven) of concentric rings due to the bombardment of the mica by the α -rays which are emitted by the uranium or the thorium, as the case may be, and their products of disintegration. The outermost of these rings is due to radium C, the innermost to uranium or thorium. From data provided by experiment it is possible to calculate the dimensions of the rings, and in the haloes due to thorium the length of the radii obtained by direct measurement agrees very precisely with that obtained by calculation, and this agreement holds, not for some of the rings only, but for all. A similar agreement is found for the rings of the uranium haloes with the remarkable exception of the innermost two, due to uranium and its immediate product, ionium. These are larger than they should be; in fact, the length of the radius of the uranium ring as actually observed is one-sixth longer than that predicted by calculation. This shows that when the haloes began to be formed—i. e., in Caledonian times—the range of the α -rays emitted by the uranium-bear-

ing crystal was greater than it is now, and hence probably that a metope of uranium then existed with possibly very different properties from the uranium now known to us.

If Professor Joly's conclusions are sound, it is clear that the uranium clock has not been keeping uniform time, and the change of rate in the disintegration of uranium is as much in question as the age of the earth. The problem is a physical one, and geologists must leave it in the hands of the physicists while anxiously awaiting its solution.

It would not be fair to end here without admitting, what Prof. J. W. Gregory's remarks will sufficiently reveal, that geologists are not an undivided family. There are some who welcome the expansive vistas now opened to their view, and Barrell has already attempted to readjust the geological perspective. He pointed out how the calculations of the earth's age, based on the thickness of deposits and the existing rate of deposition, as well as those based on the amount of sodium in the ocean, may be vitiated by a too servile interpretation of the doctrine of uniformity. The rate of disintegration of uranium may have changed, but so may the rate of denudation and deposition; so far from being constant, it may have increased with the progress of time, so that a foot of sediment which in the Pleistocene epoch accumulated, according to Barrell, in the course of 375 years would have required no less than 3,700 years for its formation in the early days of the Paleozoic era. Thus at a period when the earth was more highly charged with energy its activities were diminished. We must no longer picture a time when the earth was "young and wantoned in her prime," but must suppose that she has exchanged the passive indolence of youth for the fiery activity of old age.

In support of his views Barrell pointed out that the continents of the present day are more elevated as a whole than they were during a great part of geological time, and that their interior is not flooded to so great an extent by continental seas. It is doubtful, however, whether this would greatly affect those estimates which have been based on the maximum thickness of sedimentary deposits, for this is only to be found in the foredeeps which lay in front of mountainous lands and lands now vanished from our sight.

Barrell also laid great stress on the occurrence of gaps in the stratified series, unconformities, disconformities, and still smaller lacunæ which he termed diastemata. Of the important bearing which unconformities must have upon this discussion there can be no doubt. They were not overlooked in arriving at an estimate of 100,000,000 years. The disconformities are only now beginning to receive the attention to which their importance entitles them. In our own country we are familiar with them in the Jurassic system,

but with us this system is far from attaining its maximum thickness—it does not exceed 8,000 feet—while elsewhere it is represented by deposits of 20,000 feet or more. The presence of numerous and well-marked disconformities in the British Jurassic rocks is, therefore, not surprising; whether they have the same importance in areas of maximum deposition has yet to be shown.

The estimates based on the rate at which sodium is supplied by rivers to the sea are in remarkable agreement with those derived from a study of stratified deposits. The objection that most of the sodium in river water has been directly derived from the sea was raised long ago by Mr. Ackroyd, of Halifax, but was shown on investigation to be invalid.

No importance can be attached to the salinity of the sea in the early part of the Cambrian epoch, for as much time or more had elapsed before that period as followed after it. The first era of geological time, which has been called the Protæon, and the second, or Deutæron, are of approximately equal length. From what we know of the behavior of existing marine forms when exposed to brackish water conditions we have no reason to suppose that the Cambrian faunas could not have flourished in a sea only half as salt as the existing ocean.

Juvenile waters, often rich in sodium and chlorine, no doubt contribute to the contents of existing rivers, but if, as seems likely, they furnished a larger contribution in past times, the effect would be to shorten instead of lengthening Professor Joly's estimate.

Finally, it may be pointed out that in the only instance where estimates based on the thickness of deposits can be brought into comparison with a stricter determination of time the former have been found in excess. This stricter determination is due to Baron de Geer, who, by counting the number of annual layers of sediment left behind by the great ice-sheet in its retreat, found for the duration of post-glacial time a period of 12,000 years, and thus shorter by several thousand years than those arrived at from a study of the post-glacial deltas in the Swiss lakes.

Geologists are not greatly concerned over the period which physicists may concede to them; they do not much care whether it is long or—in moderation—short, but they do desire to make reasonably certain that it is one which they can safely trust before committing themselves to the reconstruction of their science, should that prove to be necessary.

By Prof. J. W. GREGORY, F. R. S.

The claim that geological time must be restricted within a score, or a few score, million years was regarded by most geologists with

incredulity, since a score million years was of little more use to geology than the seven days of the Pentateuch. Now that physical evidence allows the age of the earth to be counted by the thousand million years the problem is of less concern to the geologist, except from the hope that the uranium-lead ratio may fix geological dates in years, and from the interest of reconciling the conflicting results of the different methods.

The geological estimates to which most weight has been attached are based on the saltiness of the sea. The salinity argument has been widely accepted as sound in principle; the estimates varied from 70,000,000 to 150,000,000 years, and some intermediate length was regarded as inevitable. Allowances were made for various factors; but they added only a few per cent to the total, and did not multiply it by ten or more.

The validity of the salinity argument may be tested by two checks—the supply of chlorine, and the denudation required to account for the amount of sodium; and as shown by Dr. A. Holmes, each of these indicates a much longer period than the sodium.

The supply of chlorine in igneous rocks is quite inadequate to convert their sodium into chloride. Most of the sodium chloride in river water is probably marine in origin, and only the sodium in the bicarbonate and sulphate is a fresh addition to the sea. On this ground the salinity estimate should be approximately doubled. Again, to obtain all the sodium in the sea from igneous rocks would involve the denudation of improbable volumes of them, and, at the rate usually accepted, the age of the earth should be multiplied three or four fold.

The fundamental objections to the salinity argument are against (1) its assumption that the sea was originally fresh, which paleontological evidence renders improbable; the oldest fauna, the Cambrian, has the characteristic of a marine fauna, and the contrast between the fresh water and the marine faunas was as sharp in Paleozoic times as it is to-day; (2) its omission to allow for the large supplies of sodium chloride raised from beneath the earth's surface by magmatic waters; (3) its assumption of uniform denudation. The earth has probably undergone deformations that led to alternate periods of quick and slow crustal movement; during the times of repose the surface would have been planed down and rivers would have become sluggish and denudation slow. As the earth is now under the influence of a time of quick movement, denudation is faster than the average. A multiplication of the earth's age fivefold for this difference would not be excessive.

During quick crustal movement volcanic action would be more powerful, the discharge of hydrochloric acid and sodium in hot

springs would be increased; and as denudation is now acting on land in which sodium chloride has been produced in unusual quantities by volcanic action the estimated age of the earth must be again extended. The rhythmic acceleration of geological processes lengthens the estimates based on sedimentation, but would affect the biological argument inversely, since at periods of rapid physical change biological change would have been quickened, and thus the occasional abrupt introduction of a new fauna does not necessitate so long an interval as has been thought.

The best-known geological estimates of the age of the earth require to be multiplied ten or twenty fold in order to agree with the physical estimates, but this increase is consistent with the geological evidence.

By DR. HAROLD JEFFREYS.

The rate of denudation must have varied very considerably during the earth's history, for it depends on both the height of the land and on the meteorological conditions, both of which have certainly changed very much from time to time. The consistency of the various geological methods among themselves does not prove that there has been no change in the rate of denudation, for such a change would affect them all in the same ratio.

Professor Eddington's argument shows that there must be an unknown source of energy in the Cepheid variables. It is possible, however, to infer from the condition of the earth that its own age must be much greater than the Kelvin theory allows, and therefore the sun itself must have such a source of energy. The rate of increase of temperature downwards in the earth's crust is the sum of three parts, one depending on the original temperature at the surface, one on the original increase of temperature downward, and one on the radio-active emission of heat. With the best data available, supposing the time elapsed since solidification to be 1.6×10^9 years, all the known facts regarding the earth's thermal condition can be coordinated. If the age is supposed to be 1.6×10^7 years, however, the data can not be reconciled; the part of the increase of temperature downwards depending on the initial temperature at the surface is by itself greater than the present rate.

If we force an approximate agreement by supposing that the original temperature was uniform and that radio-activity does not exist at depths greater than a kilometer, we can calculate the amount of surface compression available for mountain building, the thickness of the layer of the crust which has cooled considerably and therefore become geologically strong, and the depth to which compressive movements in the crust extend. In each case the results are inconsistent with the geological and geodetic evidence, while the greater

estimate of the age of the earth agrees well. We have, in fact, the following comparison:

	(calculated.		Actual.
	Assumed age of earth.		
	1.6×10 ⁹ years.	1.6×10 ⁷ years.	
Area compressed (km. ²).....	49×10 ⁶	5×10 ⁶	>19×10 ⁶
Greatest depth of considerable cooling (km.).....	200	30	100-400
Depth of compressive movements (km.).....	70	1	>10

I do not agree with Lord Rayleigh's suggestion that the earth must be becoming hotter. That hypothesis is not acceptable on cosmogonical grounds, and Doctor Holmes has shown that it is impossible to reconcile it with the existence of volcanic temperatures, and that there must be a concentration of radio-active matter in the upper layers of the crust. Doctor Holmes has told me privately that there is reason to believe that in a fluid magma the radio-active materials will be concentrated in the upper layers on account of the volatility of their compounds, but I do not know whether this argument has been published. The numerical estimates here given rest on the supposition of such a concentration.

An alternative estimate of the age may be made from the tidal theory of the origin of the solar system, the only theory which is not unsatisfactory on dynamical grounds. The planets must, on this theory, have moved originally in highly eccentric orbits, and have had their eccentricities gradually reduced by the action of a gaseous resisting medium. If the density of the medium near Mercury was p , the time needed to reduce the eccentricity to its present value would be of the order of $4000/p$, C. G. S. units being used. On the other hand, the time it would take the medium to be dispersed by viscosity and diffusion would be of the order of $16 \times 10^{29}p$. These must be equal; for if the former was the greater the medium would have dispersed before doing the work, and if the latter was the greater the medium would still be a conspicuous object. This shows that the time needed was of the order of 8×10^{16} sec. or 2.5×10^9 years, agreeing with the estimate given by the uranium-lead ratios.



NATURAL HISTORY BUILDING. U. S. NATIONAL MUSEUM. SOUTH FRONT.

THE DEPARTMENT OF GEOLOGY OF THE U. S. NATIONAL MUSEUM.

By GEORGE P. MERRILL.

[With 20 plates.]

INTRODUCTION.

The Geological Department, as an integral part of the National Museum, dates from the appointment of Dr. George W. Hawes as curator, in 1880, after the completion of the brick building on the south side of the Smithsonian grounds, now occupied by the Department of Arts and Industries. Prior to this time, owing to the limited amount of space that could be devoted to Museum purposes in the Smithsonian Building, collections were necessarily small and development impossible. At the time Doctor Hawes entered upon his duties as curator, he also assumed charge of that branch of the Tenth Census relating to the quarry industry, and to this he devoted a large share of his attention during the brief period of his incumbency. To the Centennial Exposition of 1876, the United States Land Office and the various United States geological surveys and exploring expeditions, the department is largely indebted for whatever material it possessed prior to the date mentioned. Since that time the administration has undergone various changes, and the entire department moved from the brick building on the south side of the grounds to the new granite Natural History Building on the north side. The present paper is intended as an outline guide to the collections, and as well, to show the scope of the department and to what extent it is fulfilling its part as a Government repository for materials of scientific interest and value. The chief sources of its material, it may be well to add, are the various bureaus of the Government (particularly the United States Geological Survey), which by law are directed to deposit in the National Museum all collections "when no longer needed for investigations in progress."

With reference to the arrangement of the exhibits, it may be well to state that the space assigned to geology is not such as to make a strictly systematic arrangement of the collections desirable or practicable. Certain halls are best adapted to the exhibition of a particular class of material and quite unsuited for others. A collection

of small objects, for instance, would be quite lost in the large main hall on the ground floor, although it is admirably adapted to the use to which it is now put—that of an exhibit of fossil vertebrates. As here described, the visitor enters this hall from the rotunda at its western end, with the side halls on the south and north devoted to invertebrate fossils and fossil plants. Thence one passes northward into the east range devoted to physical and chemical geology. Returning to the rotunda once more and proceeding to the second floor, the mineral collections will be found on the south side of the east wing and, at the east end and on the north side of this same wing, the collections of ores and other material of economic interest. Expressed in tabular form, and as shown by the diagrams (fig. 1 and 2) the order of arrangement is as follows:

First floor—

Fossil invertebrates, east wing, south side.

Fossil vertebrates, east wing, center and east end.

Fossil plants, east wing, north side.

Physical and chemical geology (including petrology and meteorites), east range.

Second floor—

Minerals, gems, and precious stones, east wing, south side.

Economic geology, east wing, east end, and north side.

It may be well to state here, that the value of geological material for purposes of study and research is as a rule but slightly dependent upon its value for exhibition purposes. Hence it follows that a very considerable proportion of the collections is stored away in drawers, inaccessible to the general public, but available for study to any properly accredited student. The specimens thus stored away, constituting what is known as the study series, run numerically in hundreds of thousands, or even millions if the smaller invertebrate fossils are considered individually. Many of these are types, i. e., are the identical specimens “used by the author of a systematic paper, as the basis of detailed study, and as the foundation of a specific name.” As long ago as 1905 there were in the division of invertebrate fossils alone some 11,490 types representing 6,100 species¹ and at the present time there are probably at least twice that number. Some of the more important of the collections in this study series are enumerated on pp. 269–271.

DIVISION OF PALEONTOLOGY.

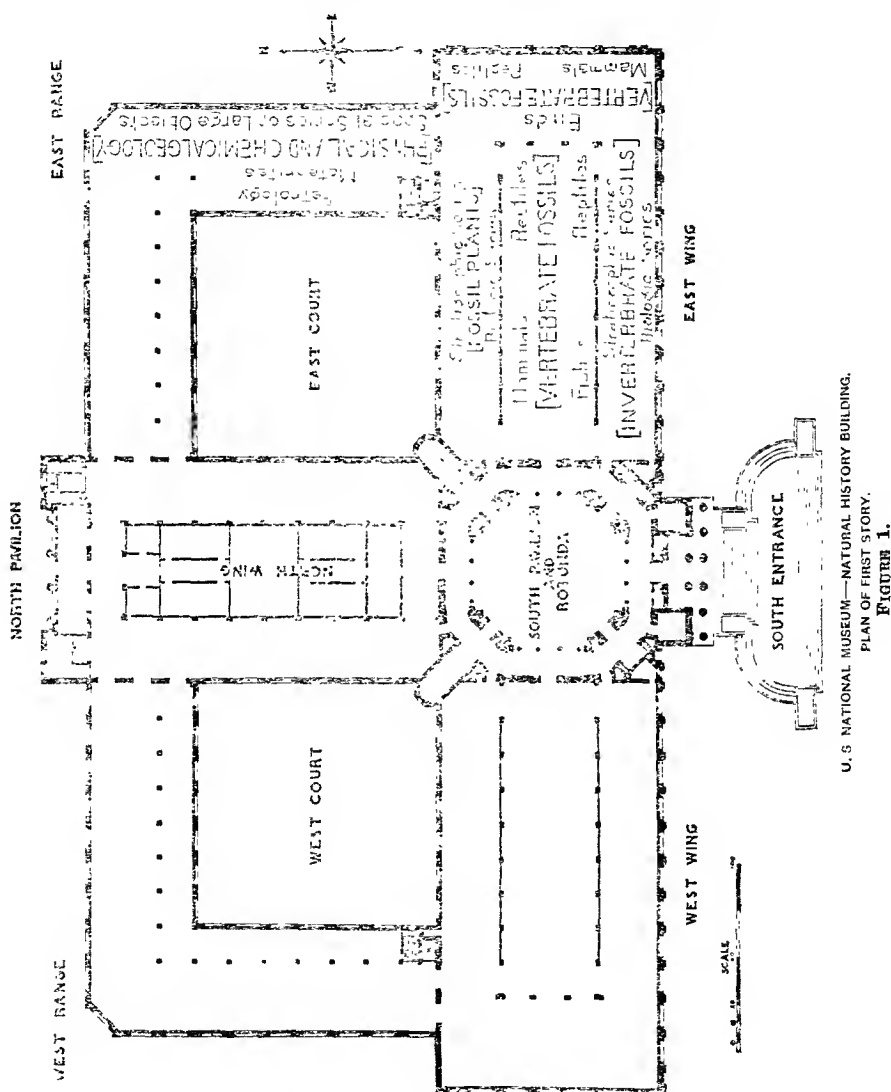
SECTION OF INVERTEBRATE FOSSILS, EAST WING, FIRST FLOOR.

In this division the exhibits are arranged in three definite series: (1) a stratigraphic series, in the long continuous case along the

¹ See catalogue of the Type and Figured Specimens of Fossils, Minerals, Rocks, and Ores in the U. S. National Museum, Bull. 53, U. S. N. M., 1905.

north wall; (2) a biologic series, along the south wall in separate cases, each of which is devoted to some special class of animals; and (3) a line of large exhibits, through the center of the hall, illustrating the various phenomena connected with the formation of stratified rocks and their contained fossils.

Each of these three series is arranged primarily for a general



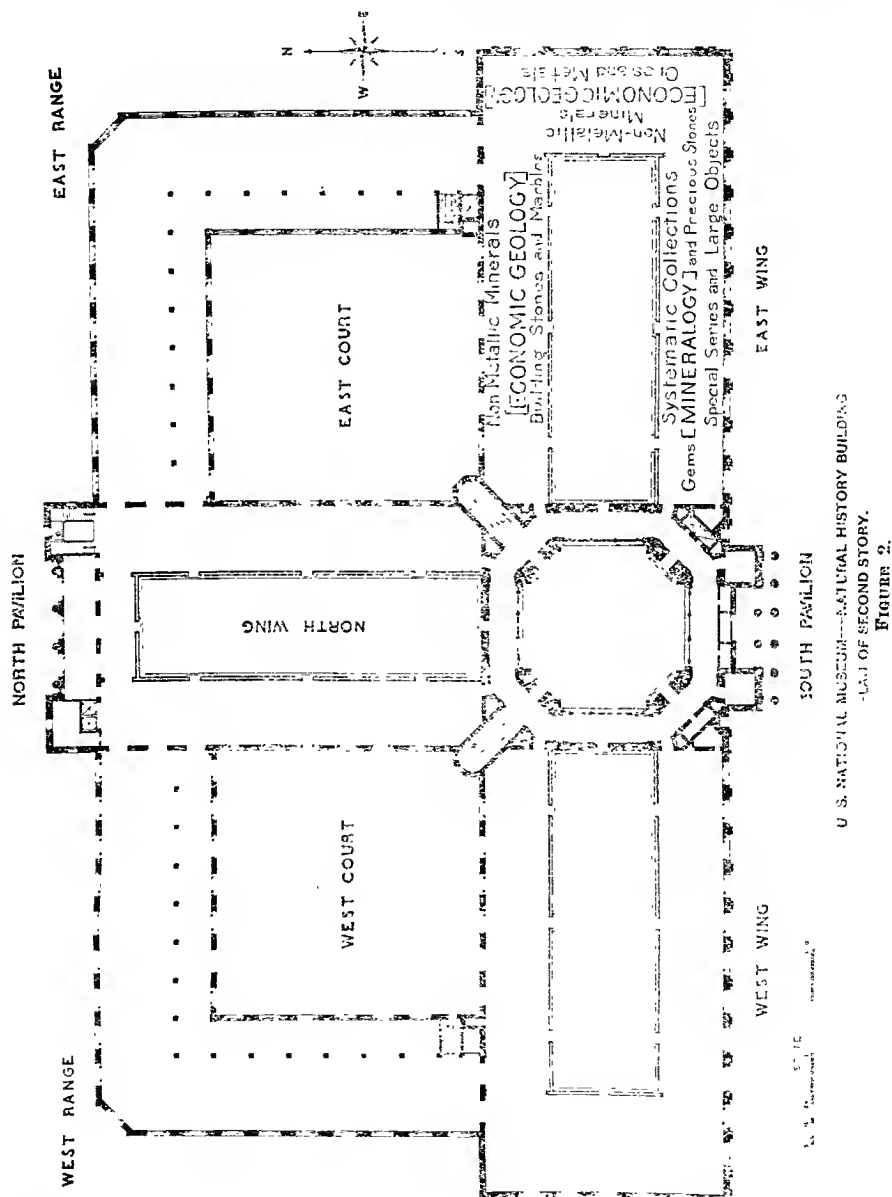
U. S. NATIONAL MUSEUM—NATURAL HISTORY BUILDING.
PLAN OF FIRST STORY.

FIGURE 1.

public which may have little interest in scientific names and technical descriptions. Therefore the usual labels giving only the scientific name and locality of various forms on exhibition are here replaced by brief descriptions of the specimens in plain English. For

the benefit of the scientific visitor the technical names are introduced in a subordinate position.

Geological phenomena.—The line of exhibits through the center of the hall comprising large objects of geological and paleontological



U. S. NATIONAL MUSEUM—NATURAL HISTORY BUILDING
—PLAN OF SECOND STORY.
Figure 2.

interest, each of which illustrates some definite chapter in the earth's history, will perhaps be most attractive to the majority of visitors (pl. 2, fig. 1). Near the entrance, as an example, is a slab of Cambrian sandstone, mounted as it was quarried out of the solid rock, and

representing the solidified sand of a very ancient sea beach. Besides preserving the original ripple marks, it is crisscrossed by tracks not unlike those of an automobile tire but in reality representing the impressions left upon the sea beach by a large wormlike animal. Following this fossil sea beach is a base containing slabs of shale, sandstone, and coralline limestone, each crowded with fossil remains and representing types of near-shore sedimentation. Nearby is a mount of conglomerate, a type of rock in which fossils are less often found. Each of these tells its own story. One specimen, the "edgewise" conglomerate, is a fragment of a formation 3,000 feet thick, extending throughout the Appalachian area and made up of slivers of limestone standing on edge. Another has a different history, as it is composed of rounded quartz boulders. A third contains only angular boulders of limestone forming a "breccia," while still another is a consolidated mass of scratched glacial pebbles.

Near at hand is a large slab of Devonian limestone composed entirely of the stems and calices of a species of gigantic fossil sea lily. This slab formed part of a layer outcropping along the bluffs of the Mississippi River south of St. Louis, Mo. Passing other exhibits in this series, attention may be directed to a limestone slab of considerable size showing a stratigraphic unconformity, or expressed otherwise, affording an actual illustration of the dividing line as registered in the rocks, between two great periods of the earth's history. Nearby are large masses of limestone showing the ancient plant and animal remains to which they owe their origin. Another large rock fragment illustrates the formation of the well-known fertilizer, calcium phosphate, from small phosphatic shells.

The differences between the faunas or assemblages of animal life in the different geological periods is shown by two exhibits.

The first, from the Frank Springer collection, is a fragment of a Cretaceous sea bottom exhibiting a colony of fossil crinoids (*Uintacrinus socialis* Grinnell). The slab (pl. 3, fig. 1) is 7 by 8 feet in diameter and is the remnant of a lenticular plate, originally upward of 50 feet in diameter, composed of the remains of a large colony of these free-floating organisms, which swam vigorously by means of their long arms. They frequently collected in dense swarms with arms and pinnules intertwined, and thus perished, the entangled mass sinking to the bottom, where, as in this case, it was flattened and embedded in the soft mud. With time and pressure the mass became consolidated into a thin plate of limestone, with the crinoids well preserved on the under surface. This, after being lifted out of the quarry, and freed from the fine adherent matrix, is now exposed to view. Nearly all of this colony was destroyed by erosion before its discovery, and the parts recovered were necessarily more or less fractured, but the

pieces, for the most part, are fitted together in their natural positions. Associated with these colonies of *Uintacrinus* are beds of a small oyster, as shown along the margin of this slab.

Every characteristic structure of this crinoid is here illustrated by one or more individuals. About 350 calices are exposed upon the surface; 90 are in position to show the base, of which 53 are monocyclic, and 37 dicyclic. Several have the arms visible to great lengths, preserving the details of the delicate pinnules as perfectly as if freshly dredged from the sea. One shows the disk, or tegmen, with its black carbonaceous membrane, from which the food grooves pass to the outstretched arms. From other specimens, it is known that the arms of this species have a spread of 8 feet, being the largest known crinoid, fossil or recent.

A portion of this specimen is the original of Plate VIII, of Mr. Springer's memoir on *Uintacrinus* (Memoirs Museum Comparative Zoology, Harvard, vol. 35, pt. 1).

The second is a large limestone slab of much greater geological antiquity, namely, Early Silurian, which consists almost entirely of primitive brachiopod shells and bryozoa. Again, there is a sandstone slab from the Eocene formations outcropping along the Potomac River below Washington which, geologically speaking, is of comparatively recent age, a fact which is indicated by the very modern looking shells occurring in it in great abundance. Finally an exhibit of fossiliferous stratified rocks, limestone and interbedded shales, with two distinct coral reefs preserved. The mass was obtained from the rocks of the Richmond formation (uppermost part of "Cincinnatian group") near Louisville, Ky. Its purpose is to show the importance of the ancient life of the globe in the formation of rock strata. The lowest layer of limestone is composed largely of fossil brachiopod shells. Next above is a layer with scattered corals belonging to a long-tubed species (*Columnaria calicina* Nicholson), probably torn by waves from a near-by coral reef. Overlying this is a limestone stratum largely made up of the twiglike stems of stony bryozoans (Trepotomata).

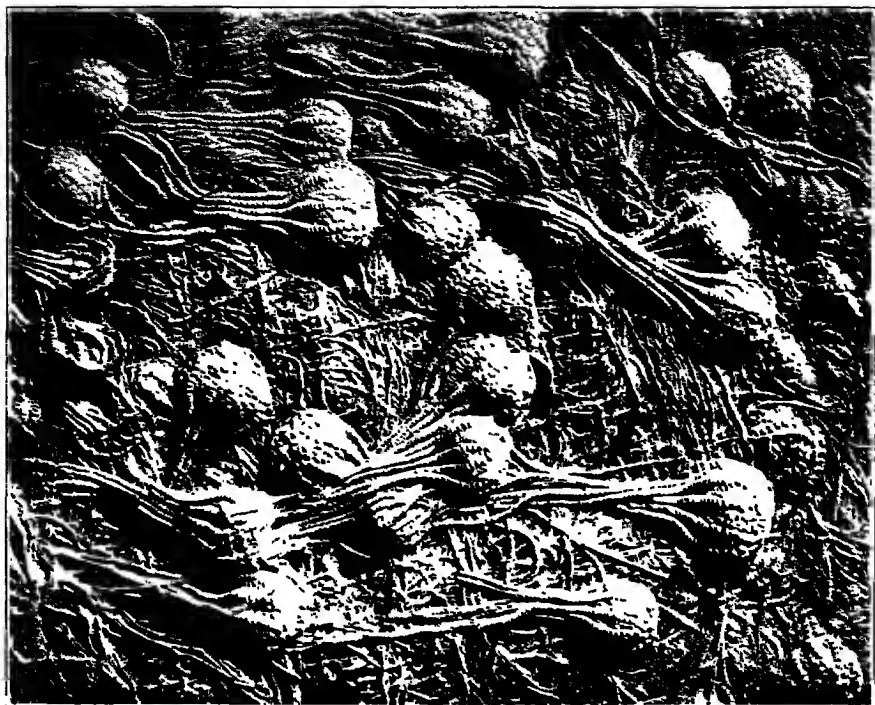
The main reef of corals is chiefly composed of the rounded heads of three species of honeycomb corals, some with radial partitions in the tubes (*Columnaria alveolata* Goldfuss), others without such partitions (*Columnaria vacua* Foerste), and still others with spongy walls (*Calapoecia cribriformis* Nicholson). Large stems of fluted or nodular hydrozoans (*Beatricea*) are scattered among the honeycomb coral masses. Horn corals (*Streptelasma rusticum* Billings) are to be seen in both the lower and upper coral beds. The spaces between the limestone layers and also between the heads of coral are filled with clay which contains many other examples of fossil



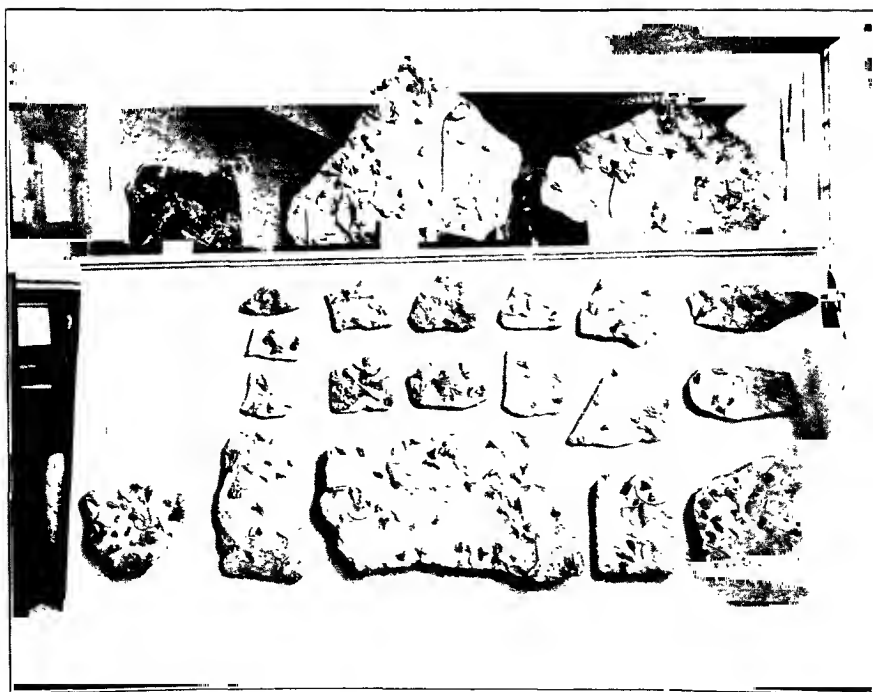
1. EAST WING, FIRST FLOOR, SOUTH SIDE. INVERTEBRATE FOSSILS.



2. EAST WING, FIRST FLOOR, NORTH SIDE. FOSSIL PLANTS.



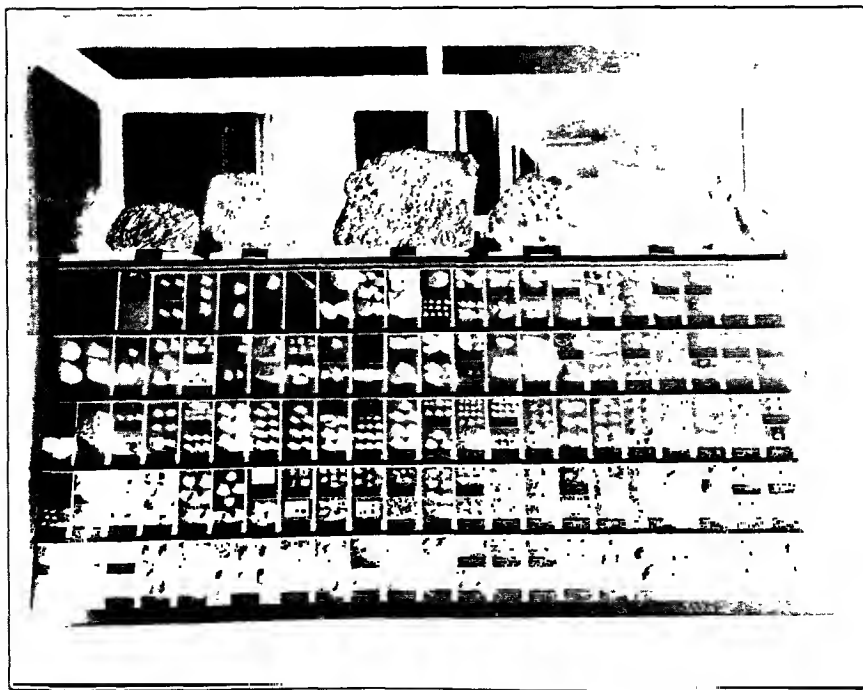
1. PORTION OF SLAB OF UINTACRINUS.



2. CASE OF CRINOIDS.



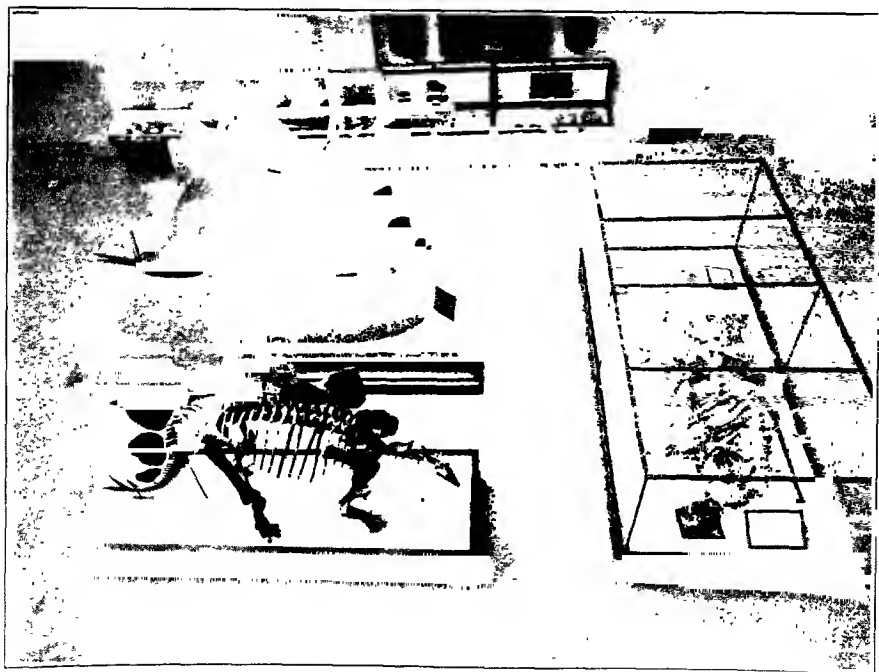
1. CAMBRIAN TRILOBITES IN SHALE.



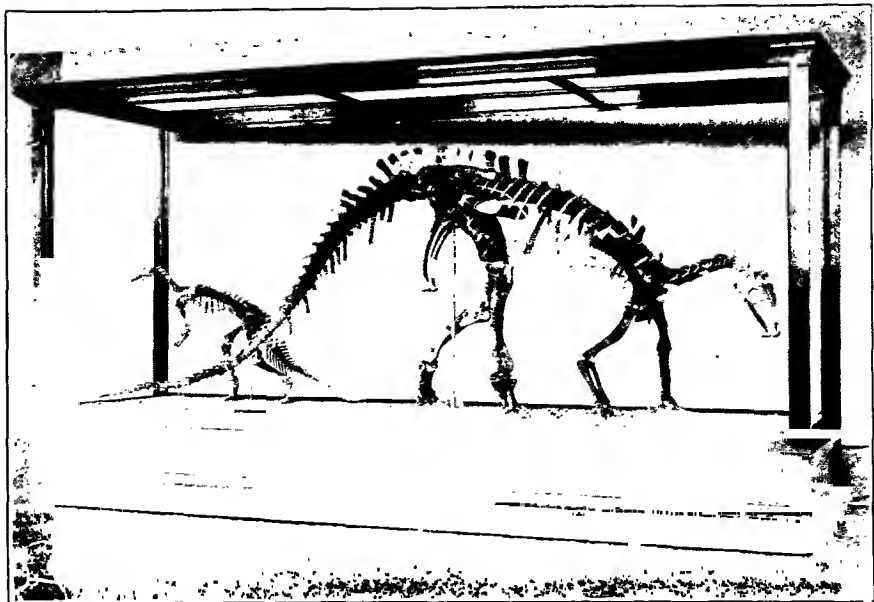
2. CASE OF INVERTEBRATE FOSSILS.



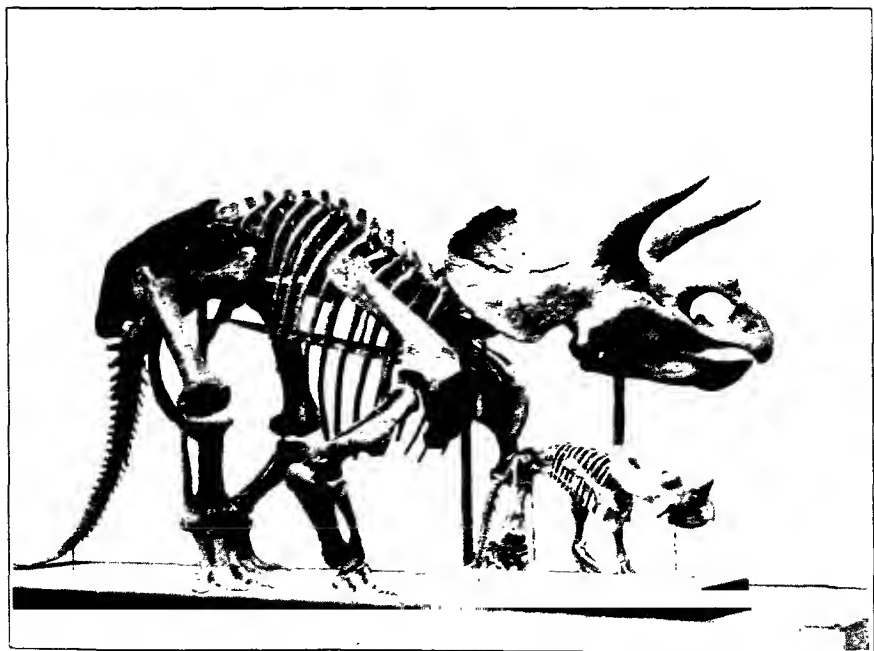
1. EAST WING, FIRST FLOOR. VERTEBRATE FOSSILS.



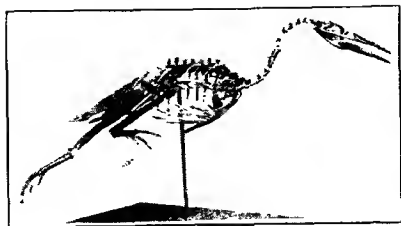
2. STEGOSAUR GROUP.



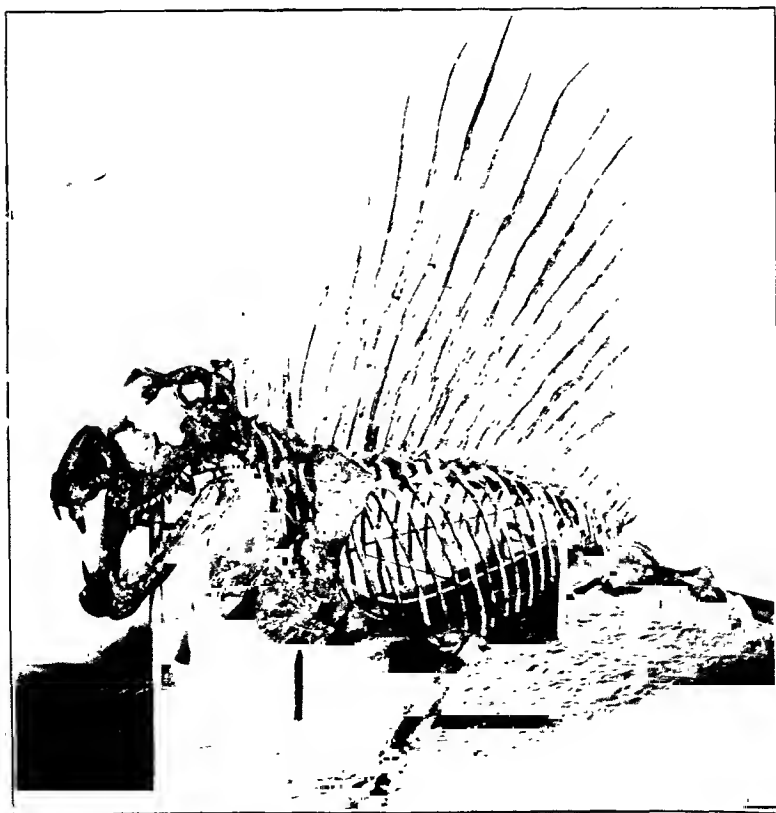
1. MOUNTED SKELETONS OF CAMPTOSAURUS.



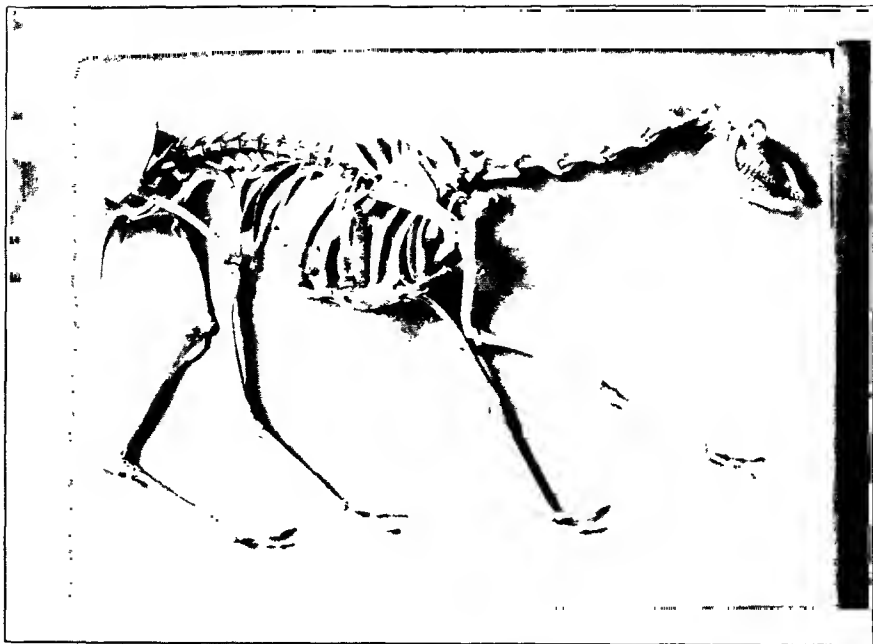
2. MOUNTED SKELETONS OF TRICERATOPS AND BRACHYCERATOPS.



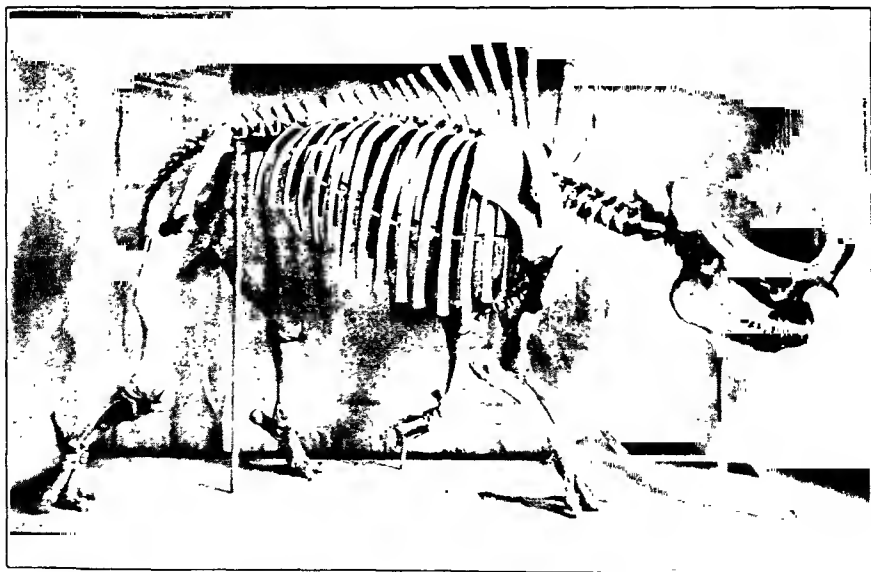
1. TOOTHED BIRD, (HESPERORNIS.) 2. HORNED RODENT, (EPIGAULUS HATCHER.)



3. SPINED LIZARD DIMETRODON GIGAS.



1. A FOSSIL CAMEL,



2 A TITANOTHERE (BRONTOTHERIUM HATCHERI).

life. This clay represents the mud which was deposited on the sea bottom, while the limestone layers resulted from the cementation by calcareous matter of the remains of animal life.

Explanatory labels of this as well as most of the other large exhibits of this nature, bear photographs showing the original position of the specimens as exposed in the field.

Stratigraphic series.—The stratigraphic series in the long continuous case against the north wall (see right-hand side, pl. 2, fig. 1) is especially adapted for the serious student of geology. It contains in the sloping portion selected series of characteristic fossils of each of the geologic formations, while above in the upright part is a corresponding series of hand samples of the typical rocks. Explanatory labels are numerous, while photographs of type areas of outcrop and maps showing the distribution of the various formations are included, giving the student here in small compass as much information on each formation as is possible under the conditions.

Structure section across continent.—Of equal or greater interest is the painted geological section 90 feet long above the upright case extending the entire length of the hall. This represents the sedimentary and igneous rocks exposed on the surface along an east-west line across the United States. The section does not follow a straight line across the continent being drawn through those areas where the greatest amount of geological data is available.

Beginning at the Pacific Ocean, the line crosses the San Francisco peninsula and continues diagonally northeastward to the Sacramento Valley. This portion is based on a manuscript section made by Prof. A. C. Lawson, of the University of California. From the Great Valley to the southwest corner of Nevada the work of the U. S. Geological Survey has furnished the data. Here connection is made with the work of the survey of the Fortieth Parallel, whose sections through Nevada, Utah, and Wyoming are utilized. From the Wasatch Range the line runs north of the Uintah Mountains to a point north of Leidy's Peak. Here there is a change in direction to the southeast, and the Uintah Range is crossed diagonally, the line being carried across the Green River Canyon at Split Mountain and the western end of the Yampah Plateau. From this point to the Elk Mountains in Colorado the section is based on the work of the Hayden Survey. In the Elk Mountains the United States Geological Survey quadrangles were utilized. From the Elk Mountains to Pike's Peak and eastward in Colorado, the work of the Hayden Survey is again the source of the data. From Pike's Peak eastward to St. Louis the line is practically straight, and in Kansas and Missouri it is based on the work of the geological surveys of those States. From St. Louis the line is again deflected to the southeast, so as to make connection with the work of the U. S.

Geological Survey in the Appalachians of eastern Tennessee. In Illinois and Kentucky the work of the respective State surveys was used. From Tennessee through North Carolina to Pimlico Sound and the Atlantic Ocean, the section of W. C. Kerr of the North Carolina Geological Survey was followed.

The horizontal scale is 2 miles and the vertical 4,000 feet to the inch. In order that the geologic structure might be better shown, the lower line of the section was carried 5,000 feet below sea level.

The section is especially interesting in that it illustrates the relation between geology and geography. For example, the low lying Atlantic Coastal Plain is seen to be formed of horizontal unconsolidated sands and clays of comparatively recent origin; the higher Piedmont Plateau is underlaid mainly by greatly contorted and deeply eroded igneous rocks; the Appalachian Valley is a great limestone area; the Cumberland Plateau of horizontal sandstones, shales, and coal beds, forms the great Eastern coal field; the Mississippi Valley is composed almost entirely of horizontal Paleozoic rocks, and the Great Plains of Mesozoic and Cenozoic strata. It brings out also in strong contrast the deeply eroded Appalachian areas, where the old mountain ranges are worn down almost to their roots, with the more recently uplifted and less eroded Rocky Mountains and other still more recent ranges to the west. The Rocky Mountain and Great Basin areas show further numerous volcanoes which have broken through the greatly disturbed and uplifted strata and poured out great lava flows at various intervals. Faulting or dislocation of the strata in this area is plainly evident along the west front of the Wasatch Mountains in Utah, in the Basin Range Mountains, and also along the Coast Range of the Pacific, where occurred the renewal of faulting producing the San Francisco earthquake of 1906.

Above this structure section various large fossil invertebrate animals are mounted on the wall. Conspicuous among these are several exceptionally large cephalopods, ancestors of the pearly nautilus.

Biological series.—The biological series contained in special upright cases along the south wall (south or left side, pl. 2, fig. 1) gives a comprehensive idea of all the different types of invertebrate life of past ages. This exhibit is designed more especially for students and collectors. Beginning with the simple one-celled protozoa and proceeding with the sponges and corals through all the higher types of invertebrate animals, one or more special cases are devoted to each of the classes. As the structure of the fossil forms is sometimes obscure, numerous drawings and photographs are introduced. Of exceptional interest in this series are the fossil sea lilies forming a part of the Frank Springer collection of echinoderms. The method of showing these beautiful petrified remains, which, however, are

animals not plants, as the popular names suggest, is shown in figure 2, plate 3. Another striking object is the largest known Trilobite (*isotelus brachycephalus* Foerste) found in 1919 during the work of excavating for a dam on the Ohio River near Dayton. The actual size is 8 by 15 inches. The detail with which each class of invertebrates is treated is shown in the accompanying illustration of one of the two cases devoted to fossil brachiopods (pl. 4, fig. 2). This case shows also the method of installation of small objects for exhibition purposes. The specimens are fastened to terra cotta tiles by a combination of plaster of Paris and liquid glue and the tiles are mounted between grooves on an upright or slightly sloping frame.

Faunal exhibits.—This same series of exhibits contains two faunal collections, one case being devoted to the assemblage of Middle Cambrian organisms so remarkably preserved in the rocks that the most minute details of their anatomy are preserved. The specimens shown were discovered and collected by the secretary of the Smithsonian Institution, Dr. Charles D. Walcott. Another faunal exhibit comprises the Ordovician and Early Silurian fossils of southwestern Ohio. This area is perhaps best known to all students of the science on account of the abundance and perfect preservation of its invertebrate remains. The specimens were selected from a very large number forming the I. H. Harris collection.

Only a small portion of the collection of fossil invertebrates is on exhibition, the remainder forming a study series distributed in the various offices and workrooms of the Museum under the care of specialists. This study collection, probably the largest of its kind in the world, is contained in about 20,000 standard drawers, 24 by 30 inches in size, and includes literally millions of specimens. The number of its type specimens can be judged from a list published in 1905, which occupied a volume of 704 pages; since that time almost an equal number has been added. Space will not permit mention of more than a few of the important collections contained in this series. Among them are the Walcott collection of Cambrian fossils containing the results of practically all the researches upon this group of strata; the Ulrich collection of Early Paleozoic fossils with its thousands of type specimens; the Rominger and Nettelroth collections of Silurian and Devonian fossils; the Frank Springer collection of fossil echinoderms forming the most complete series of this class extant; the Harris collection of Ordovician and Silurian fossils; the Williams and the Sherwood collections, representing a lifetime of work on the Devonian, and numerous collections of Mesozoic fossils, assembled by Dr. T. W. Stanton and his associates on the Geological Surveys; a great biological series of Tertiary mollusks assembled by Dr. W. H. Dall; and a similar stratigraphic series of Tertiary formations collected by Dr. T. Wayland Vaughan and his assistants.

SECTION OF PALEOBOTANY (FOSSIL PLANTS), EAST WING, FIRST FLOOR,
NORTH SIDE.

The exhibition of fossil plants is divided into (1) a biological and (2) a stratigraphic series. Entering this hall from the rotunda (pl. 2, fig. 2), the large upright cases occupying the east end of the hall will be noted to contain the characteristic fossil plants of each geologic formation, beginning with the oldest pre-Cambrian rocks, in which possible plant remains are represented by graphite, and continuing through successively younger and younger formations until the present time. In this series perhaps the most interesting, or at least most unique, is the case devoted to the oldest known life consisting of the remains of algæ or seaweeds. These were discovered by Dr. Charles D. Walcott in sedimentary rocks preceding the Paleozoic, hitherto believed to be devoid of life, and proved to be the secretions of calcareous seaweeds growing into coral-like plant masses which, by repetition in successive beds, formed thousands of feet of limestone. Thin sections of some of these remains have indicated the presence of bacteria at this early date in geologic history.

The stratigraphic series also contains an exceptionally fine lot of large examples of Coal Measures plants, which contributed so much to the formation of coal beds. Among the large objects forming a part of this series is the base of a trunk and roots of the Carboniferous tree *Lepidodendron*, one of the ancestors of the present day ground pines or clubmosses. This specimen from the Coal Measures of Pennsylvania, shows especially well the spreading roots, which were really underground stems adapted to growth in swampy places. On the wall at the west end of the hall is a portion of the trunk of this clubmoss extending to the ceiling and showing the diamond-shaped scars left by the fallen leaves. These clubmosses often grew to height of 100 feet or more. The logs and sections of tree trunks next to this clubmoss stump are of a silicified conifer tree from the Fossil Forest near Holbrook, Ariz. In these trunks the woody matter has been wholly replaced by silica in the form of chalcedony, jasper, and opal.

In the wall cases along the south side of the hall the exhibits are arranged in biologic order, starting at the far east end with the simplest forms of seaweeds and continuing from left to right, like the pages of a book, until the highest forms of flowering plants, like those of to-day are reached. Above these cases are large drawings showing restorations of the landscape of each geological period.

The amount of material available for exhibition is so large that only a small portion of the more showy specimens can be shown in the space assigned. Thus, for example, the very important Carboniferous clubmosses have to be restricted to a single case, in which the space is only sufficient to illustrate with specimens the anatomy of

the group and its variation in structure. A similar method is followed for all the different groups of plants, and in many cases where there are recent representatives of the same group, such examples are introduced for comparison with the fossil forms.

The exhibition series of fossil plants just described forms likewise only a small portion of the National collection. Located on the floors above the exhibition halls, where they are readily available for study, is a reserve series contained in 9,000 standard drawers, 24 by 30 inches in dimension. This study collection, undoubtedly the largest in the world, contains the types and figured specimens described in practically all of the important monographs upon the subject by the leading American paleobotanists Lesquereux, Newberry, Ward, Hollick, Knowlton, White, and Berry. It is especially rich in American Coal Measures plants and includes the great Lacoe collection of over 100,000 specimens.

SECTION OF VERTEBRATE PALEONTOLOGY, EAST HALL, FIRST FLOOR.

Vertebrate paleontology as a distinct section in the organization of the United States National Museum, has a comparatively brief history. Commencing in 1898 with the appointment of Prof. O. C. Marsh of Yale University, New Haven, Conn., as honorary curator, a portion of the collections made by him under the auspices of the U. S. Geological Survey and up to that date retained by him in New Haven, was transferred to the Museum. Prior to this time it appears that the Museum collections consisted of miscellaneous and fragmentary material from various sources, but resulting principally from the early exploring expeditions of the Government in the West. Their scientific value was, however, far beyond that of the usual fragmental materials, on account of the considerable number of types included, the work of the pioneer American paleontologists, Newberry, Leidy, and Cope.

After the death of Professor Marsh, in 1899, the entire Government portion of the collection was transferred from New Haven to the Museum at Washington. It comprised six carloads of material brought together during the 10 years between 1882 and 1892, more than half of which was still in the original packing boxes as shipped from the field. It is this material known as the "Marsh Collection," that forms a considerable bulk of the present collection of vertebrate fossils in the National Museum.

Up to 1921, 10,500 specimens have been catalogued and it is estimated that an equal number remain to be catalogued so that in all there are over 20,000 specimens in the collection. While the yearly list of accessions is not large there is a steady and healthy growth and as a whole the collection is gradually assuming a status that is

in keeping with the national character of the institution. The six principal sources of accessions are (1) purchase, of which there are but few, (2) transfer from other Government departments, (3) occasional collecting expeditions, (4) exchange of duplicate materials, (5) gift, (6) deposit. Of these numbers two and three are by all means of greatest importance numerically.

The exhibition collection, begun in a modest way more than a quarter of a century ago by the installation of a mounted specimen of an Irish Elk and casts of a Glyptodon and giant sloth, now forms a very important part of the department of geology. It may be said to have had the beginning of its present development with the mounting of the duck-billed dinosaur (*Trachodon annectens*), in 1902, the second dinosaur skeleton to be mounted in the United States, first honors having gone to Yale University, where a companion specimen was placed on exhibition the year previous.

Since 1902, and especially since occupying improved quarters and more ample show space in the new Natural History Building (pl. 5), other skeletons have been added to the exhibition series from time to time, until there is now a total of 40 articulated representatives of the three great classes of animal-life—birds, reptiles, and mammals. These vary in size from a small horned rodent (*Epigaulus hatcheri*, pl. 7, fig. 2) 12 inches in length, to the whalelike *Basilosaurus* that measures 55 feet over all. Numerically this number may appear small, but when the rarity of mountable specimens is taken into consideration and especially the great length of time required to prepare them, it makes a creditable showing for the small force engaged in the work.

The larger skeletons are arranged in the center of the main hall. In placing these more attention has been given to display and to their conformity to the space occupied than to any systematic arrangement, although the hall is roughly divided between representatives of the mammals and reptiles, the former predominating in the western half, the latter in the eastern portion. Of the larger specimens, those deserving especial mention are the *Basilosaurus cetoïdes*, a long and slender marine mammal, which occupies a prominent place in the center of the hall opposite the entrance from the rotunda. The skeleton remains of this animal were collected by Mr. Charles Schuchert in 1894 and 1896 from the vicinity of Cocoa, Fla. This constitutes the first approximately correctly assembled individual of this peculiar animal ever to be mounted. It may be of interest to recall the grotesque restoration by Koch which he reconstructed from *Basilosaurus* bones some years ago and which was widely exhibited. This restoration, which Koch called *Hydrarchos*, was made up of the bones of many individuals, and gave a very exaggerated idea of its length and proportions.

At either side of the *Basilosaurus* skeleton are exhibited fine examples of the American mastodon (*Mammut americanum*) exhumed from peat bogs in northern Indiana and southern Michigan. The so-called Irish elk (*Alce gigantea*), from the peat bogs of Ireland, with its wide-branching palmate horns, that have a spread of 8 feet, 9 inches, is a striking specimen of its kind.

Passing to the large reptilia, the most conspicuous is a mounted skeleton of the gigantic horned dinosaur (*Triceratops*), a creature with the largest head of any land animal the world has ever known. This skeleton is 20 feet in length and 8 feet in height in front of the hips, the skull being nearly one-third the total length of the animal. In addition, this skull is further characterized by the development of a great bony shield that overhangs the neck, and by two large sharply pointed horns projecting forward from above the eyes with a third smaller one developed on the nose. The three horns suggested its name, *Triceratops*, meaning three-horned face. The remains of this specimen, together with many others of its kind, are from eastern Wyoming. While *Triceratops* represents the largest and culminating group of its race, the *Brachyoceratops montanensis* is the smallest horned dinosaur yet described and one of the earliest, geologically, of this peculiar group of reptiles. This skeleton, which is a few inches less than six feet in length, has a skull that is only 22 inches long. Its diminutive size, as compared with the large *Triceratops*, is clearly indicated in plate 6, figure 2.

In addition to the two articulated skeletons mentioned above, the Ceratopsia, as this group of horned dinosaurs is named, is represented by several fine skulls and numerous other portions of skeletons. The scientific importance of the collection is notable because of the considerable number of type specimens, among which may be mentioned *Triceratops calicornis*, *T. obtusus*, *T. elatus*, *T. alticornis*, and *Dicreratops hatcheri*.

Against the north and south walls in the center of the main hall are two dinosaur skeletons mounted in high relief. On the south side is the large plant eating duck-billed *Trachodon annectens*, an animal 30 feet in length, that in life walked around largely on his strong hind limbs. This came from Wyoming also and was a contemporary of the *Triceratops* previously mentioned. On the north side stands a flesh eating *Ceratosaurus nasicornis*, a powerful but agile animal seventeen feet in length and 5 feet high at the hips. In life the creature subsisted on the flesh of other animals, as indicated by the jaws with strong, sharp-pointed teeth that were well adapted to the seizing of its prey and the subsequent tearing and rending of flesh. One of its distinctive features is the presence on the nose of a single well-developed horn. This animal is exceeded, however, in size by the

carnivorous dinosaur *Antrodemus fragilis* of which the Museum has only the skull and hind limbs as yet on exhibition.

The armored dinosaurs are well represented by a nearly perfect articulated specimen (*Stegosaurus stenops*) exhibited as found, with only the superficial sandrock cut away, which is supplemented by a mounted skeleton and a life-sized *papier-mâché* restoration, the three constituting the most complete and comprehensive exhibit of this animal known (pl. 5, fig. 2). The one retained in the rock is of great scientific importance since the large bony skin plates are retained in sequential position and show their precise relationships to the internal skeleton. It is the only specimen known in which these important features of its anatomy have been preserved. This recumbent skeleton was found in Colorado, but the somewhat smaller mounted one is from southeastern Wyoming. Other dinosaur exhibits worthy of mention are two representatives, a large and a small species, of *Camptosaurus* grouped in a single case (pl. 6, fig. 1). These are unusually complete skeletons, the bones being especially well preserved.

The *Camptosaurus* were bipedal animals; that is, they walked about on their hind legs, the body being counterbalanced by the long tapering tail. They were plant feeders and lived in Wyoming during the Jurassic period contemporaneous with the *Stegosaurus* and *Ceratosaurus* previously mentioned. It is to be recalled that when tracks of bipedal dinosaurs were first discovered in the sandstones of the Connecticut Valley, they were supposed to be those of birds, which they closely resemble.

Fossil forms of bird life are represented by a particularly well mounted skeleton of the rare toothed *Hesperornis* (pl. 7, fig. 1) from the chalk beds of western Kansas, and three skeletons of the extinct moa, bones of which are found in the swamps of New Zealand. The swimming reptiles, by a skeleton of the short necked plesiosaur (*Brachauchenius lucasi*), a skeleton of the large marine reptile *Tylosaurus* 25 feet long (pl. 10, fig. 1), and beautiful specimens of *Ichthyosaurus* and *Rhamphorhynchus* from the famous lithographic stone quarries of Germany.

The giant spined lizard (*Dimetrodon gigas*) from the Permian beds of Texas (pl. 7, fig. 3) is in many respects one of the most interesting of the entire exhibit. The high dorsal crest along the back, formed by the elongation of the spinous processes of the vertebræ, is the particularly striking feature of this animal.

In cases along the sides of the main hall and forming alcoves at the eastern end of the hall are exhibited illustrations of other extinct faunas, or evolutionary series, showing the development of certain groups. Among them should be mentioned—(1) a series of skulls and

foot bones showing the development of the horse from the primitive *Eohippus* to the modern living form, (2) one of the common land tortoise (*Stylenys nebrasensis*) showing the growth stages from the smallest to the large adult specimens, and (3) a collection representing the fauna of the Pleistocene period, which immediately preceded the present-day animals. While far from complete in its representation, it gives an idea of the character and kind of animals that lived at that time. Of special local interest are two collections from near-by sources. These are (1) a series of remains, chiefly shark and cetacean, from the Miocene formations near Chesapeake Beach, Md., and (2) a strikingly varied series of mammalian remains from a limestone cavern on the line of the Western Maryland Railway, near Cumberland. Of the first there are several almost complete skulls and two skeletons of the long and short snouted dolphinlike cetaceans; a rare and the most perfect example of the squalodon yet discovered; and several representatives of the whalebone whales. There is also a considerable series of sharks' teeth, which are the only portions of these animals which are sufficiently bonelike to have been preserved. These fragmental remains well illustrate the character of the aquatic animal life during Miocene times, when this portion of the Maryland coast was depressed beneath sea level. The second collection to which reference is made is from a limestone cavern which was cut through in the process of railway construction. From the stalagmitic and clayey matter occupying the bottom of this cave there were secured more or less fragmentary bones and skeletons of between 40 and 50 species of mammals, ranging in size from that of a small bat to an elephant. Among these are many identified with forms now living, but others extinct and of a type not now inhabiting North America. There are included in the collection remains of bats, mice, wood rats, rabbits, porcupines, woodchucks, skunks, weasels, martens, badgers, mountain lions, lynxes, wolverines, bears, peccaries of a species much larger than any now living, tapirs, horses, and antelope, the nearest living representative of which is an African species, and mastodons. The assemblage of so numerous and varied a series in one common burying ground can seemingly be accounted for only on the supposition that this cave at some earlier period was connected with the surface by a sink hole through which poured a stream of water carrying the carcasses of dead animals which had, perhaps, been drowned during a period of flood. The collection, only a few examples of which can be exhibited, is of exceptional interest in that it shows the changes which have taken place in the character of the animal life within a very recent period. Other objects of interest in this hall are the peccary (*Platygonus*), bear (*Ursus*), wolverine (*Gulo*), and wolf (*Canis*), together with skulls representing several species each of the extinct bison, muskox, horse,

and mammoth. Other cases are devoted to the Tertiary life of the continent. The fossil rhinoceroses are represented by numerous skulls and jaws and two mounted skeletons. The short-legged form (*Teleoceras fossiger*) from Kansas and *Diceratherium cooki* from western Nebraska are notable examples of their kind.

The collection of Titanotherium remains is probably the most ambitious display of this great group of extinct mammals ever attempted. Twenty-two selected skulls, representing 6 genera and 20 species, together with a mounted skeleton of *Brontotherium hatcheri* makes an exhibit of exceptional merit (pl. 8, fig. 2).

DIVISION OF PHYSICAL AND CHEMICAL GEOLOGY.

SECTION OF SYSTEMATIC GEOLOGY, EAST RANGE, FIRST FLOOR.

In this division attention is given to the bringing together and, so far as is practicable, preparing an exhibit of materials bearing upon the history of the earth in its cosmical aspect and illustrative of its composition and structure. It begins with a series, showing so far as their nature will permit, (1) the chemical elements constituting rocks, (2) the minerals constituting rocks, (3) the physical properties of rocks as structure, color and fracture, and (4) the kinds of rocks (Petrology). (See pl. 10, fig. 2.)

(1) *Chemical elements*.—Although there are some 80 known elements, but 16 occur in any great abundance or form more than an extremely small portion of the earth's crust. These 16, exhibited and arranged according to their chemical properties and in the order of their abundance, are as follows:

Metalloids:

Oxygen.
Silicon.
Carbon.
Sulphur.
Hydrogen.
Chlorine.
Phosphorus.
Fluorine.

Metals:

Aluminum.
Calcium.
Magnesium.
Potassium.
Sodium.
Iron.
Manganese.
Barium.

(2) *The minerals constituting rocks*.—This series represents the various compounds of the elements mentioned above in the form of recognized mineral types, only such being shown as are commonly found in the form of mineral aggregates to which the term rock is applied. As exhibited they are divided into primary, secondary, and accessory, according as they are products of the first consolidation of the rock mass, or due to secondary changes, or are accidental constituents.

(3) *The Physical and Chemical Properties of Rocks*.—Selected specimens illustrating structure—the manner in which their various

constituent parts are grouped together—the specific gravity, the chemical composition, color, and fracture, and manner of breaking of rocks, each feature of which is illustrated by one or more specimens. It is common to divide these structural features into two classes according as to whether or not they are visible by the unaided eye or only by a magnifying power. The first are known as the macroscopic or megascopic, the second the microscopic structures. The microscopic structures are made visible by means of thin sections sufficiently transparent to be studied under the microscope. A series of these sections is shown, and also, in the transparencies in the windows, the appearance of certain portions as seen under a high magnifying power.

Other series illustrate the specific gravity, chemical composition, and color of rocks, and, so far as possible, explain the agencies to which these characteristics are due.

(4) *The Kinds of Rocks (Petrology)*.—These preliminary series are followed by one much more extensive, including all the more important types of rock masses. These are shown mainly in the form of what are known as hand specimens, approximately 3 by 4 inches in diameter, and 1 to 1½ inches in thickness. They are grouped under four main heads, the distinctions being based upon their origin and structure. Each of the main divisions is again divided into groups or families, the distinctions being based mainly upon mineral and chemical composition, structure, and mode of occurrence. The collection as at present exhibited comprises some 1,700 specimens, grouped as follows:

I. *Aqueous rocks*.—Rocks formed mainly through the agency of water as (a) chemical precipitates or as (b) sedimentary beds. Having one or more essential constituents; in structure laminated or bedded; crystalline, colloidal or fragmental, never glassy.

II. *Aeolian rocks*.—Rocks formed from wind-drifted materials. In structure irregularly bedded; fragmental.

III. *Metamorphic rocks*.—Rocks changed from their original condition through dynamic or chemical agencies, and which may have been in part of aqueous and in part of igneous origin, having one or many essential constituents. In structure bedded, schistose, or foliated.

IV. *Igneous rocks—Eruptive*.—Rocks which have been brought up from below in a molten condition, and which owe their present structural peculiarities to variations in conditions of solidification and composition, having, as a rule, two or more essential constituents. In structure massive, crystalline, felsitic or glassy, or, in certain altered forms, colloidal.

For the purpose of further elucidation, there are arranged in cases on the east side of the hall several series of the same materials as the last, but in larger sizes, and so far as possible or desirable in the actual condition in which they were found, the idea being to illustrate by specimens the results of sundry geological processes, as solution and deposition, vulcanism, rock weathering, etc. The descriptive matter below is in part a transcript of labels, interspersed with references to particular specimens.

LIMESTONE CAVERNS AND ASSOCIATED PHENOMENA.

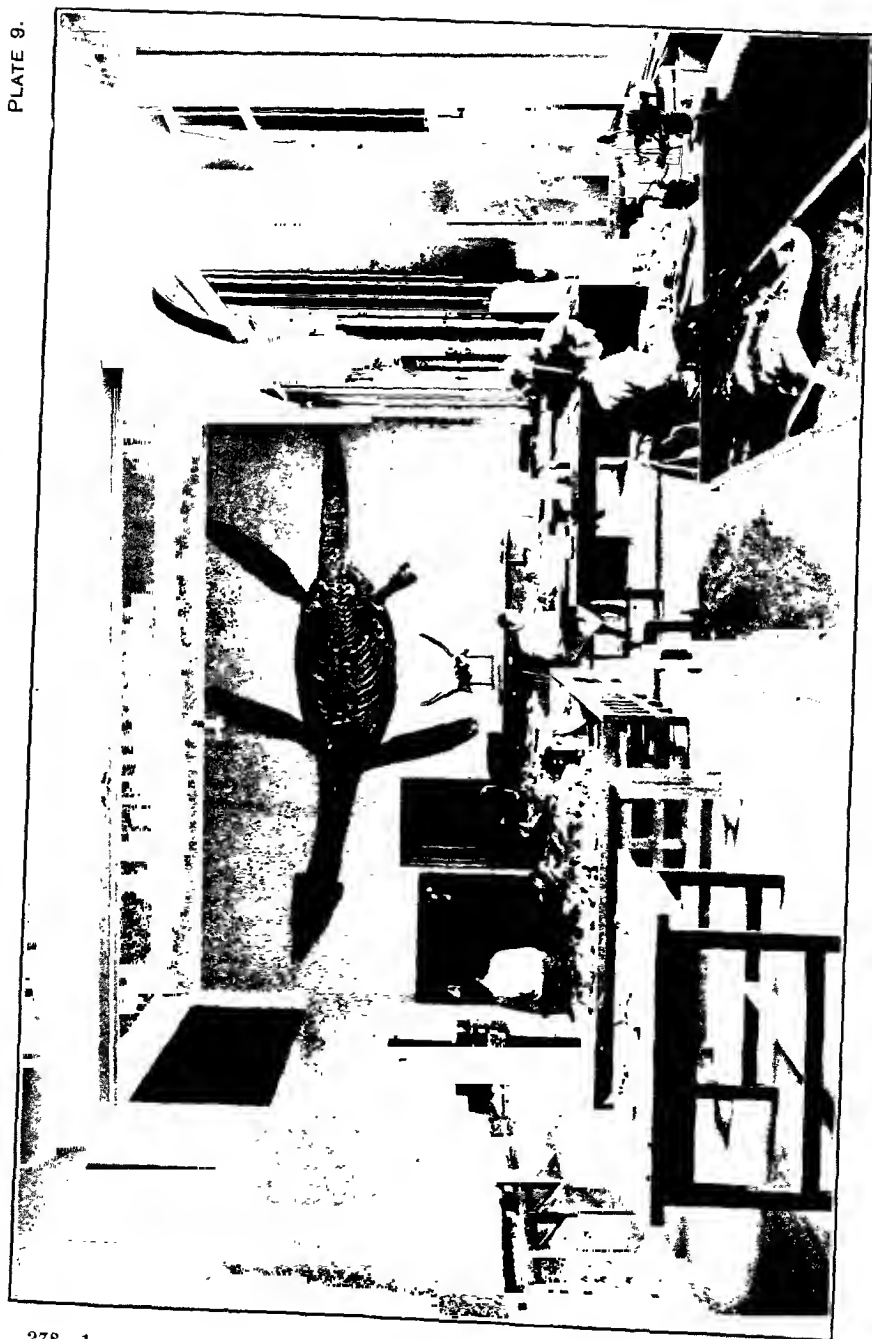
The series of objects included in this exhibit are designed to show, either by actual specimens or illustrations, the various stages in the history of a limestone cave. To this end are shown: (1) A theoretical sketch showing the mode of formation by solvent action of water. (2) Actual plans and sections of caves. (3) Cave interiors: shown by photographs and drawings. (4) As supplementary to the above, a series of cave deposits (stalactites, stalagmites, etc.) (pl. 11, fig. 3). These in part are cut and polished to show color and structural variations. (5) The possible economy of caves, shown by blocks of cave marble, nitrous earths, and other salts. (6) Cave life, shown by insects, blind fish, crayfish, bats, etc. (7) The occupancy of caves by human beings as temporary dwellings; shown by illustrations and specimens of bone breccia and implements of human workmanship found in caves. Of particular note in the exhibits are the large stalagmitic and stalactitic forms from Luray, Va., and the complete section, as formed by nature, from the Marengo Cave in Indiana (pl. 11, fig. 2). This bears the following legend:

SECTION OF MARENGO CAVE.

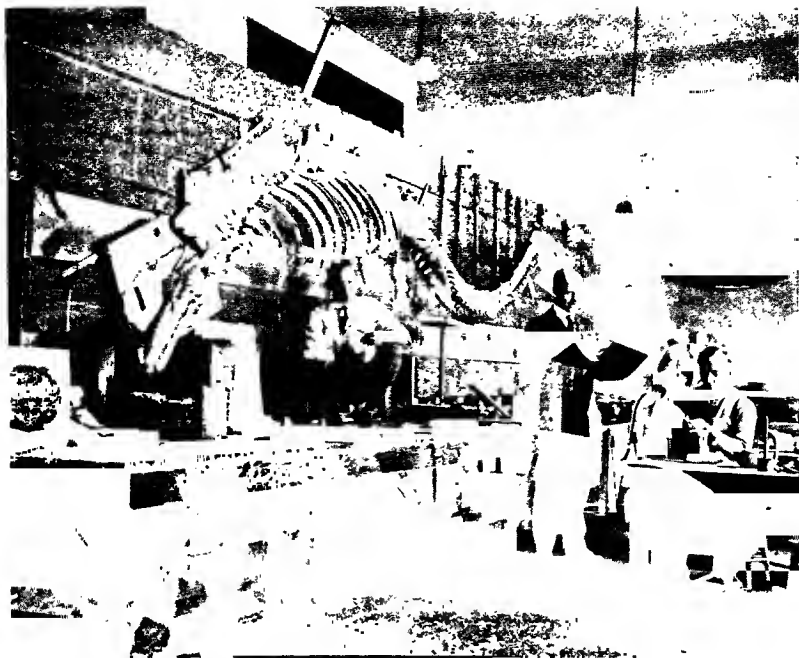
MARENGO, INDIANA.

60,634.

The stalactites and stalagmites are in their original position as formed in the cave. The longer ones had united at the ends and it was necessary to saw them apart before removing. The smaller stalactites were removed separately, it being found impossible to cut away the material of the roof with the stalactites attached. Hence, while their position is not absolutely as formed, it is sufficiently accurate for all practical purposes. The section illustrates a common but easily explained phenomena in caves: That stalactitic growths of considerable size are often produced without corresponding stalagmites. The converse of this is also true. The explanation is found in the fact that owing to conditions of evaporation, all the lime is deposited either before or after dropping from the pendant stalactite, instead of being nearly equally divided between stalactite and stalagmite, as is frequently the case.



LABORATORY OF VERTEBRATE PALEONTOLOGY.



1. THE SWIMMING REPTILE, TYLOSaurus DISPELOR, IN PROCESS OF MOUNTING FOR EXHIBITION.



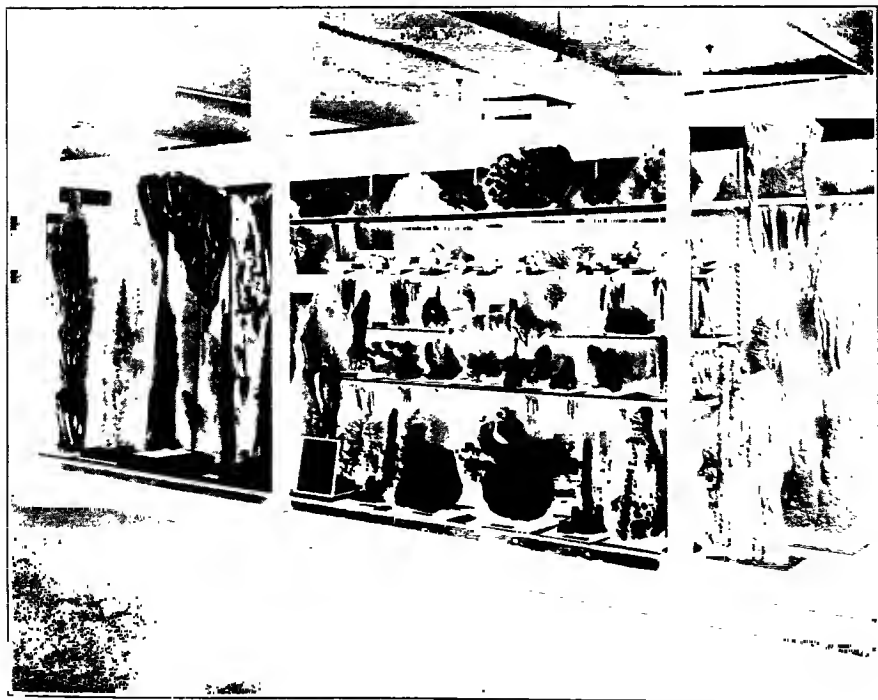
2. EAST RANGE. PHYSICAL AND CHEMICAL GEOLOGY.



1. CURVED CALCITES.



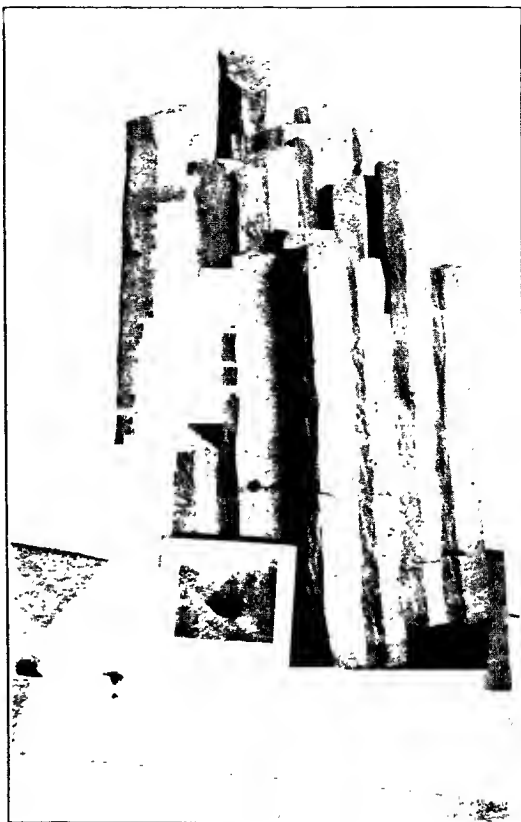
2. SECTION OF MARENGO CAVE.



3. CASE OF STALACTITES AND STALAGMITES.



1. GLACIATED LIMESTONE.



2. BASALTIC COLUMNS.



3. COMPRESSED AND FAULTED SLATE.



1. GLACIAL FLUTING.



2. GLACIAL POTHOLE.



RELIEF MAP OF UNITED STATES WITH ICE SHEET OF GLACIAL PERIOD.

Attention may also be called to the peculiar curved and distorted stalactitic forms from this same cavern and the fluted and otherwise corroded blocks of limestone illustrating the solvent action of carbonated waters in the formation of caves. The bottle and wineglass coated with the calcareous deposit illustrate the comparative rapidity with which the deposition may take place under favorable conditions, while the mummified rat testifies to the dryness of the older portions of caves like Mammoth and Marengo, where solution and refilling processes have practically ceased.

Following this somewhat extended series are two cases likewise filled with products of water solution and deposition, but of a somewhat different nature. The more striking are the mushroom-shaped tufas formed through the gradual evaporation of the calcareous waters of Pyramid Lake in Nevada, and the trunklike chalcedonic forms lined with crystalline quartz or calcite from southeastern Wyoming.

VOLCANOES AND VOLCANIC PHENOMENA.

The collections are designed to show by means of maps, models, illustrations, and actual specimens as much regarding volcanoes in their active and incipient stages as space will permit.

The general scope of the exhibit is as below:

(1) Volcanic products, shown by specimens selected to illustrate (*a*) characteristic forms of lava, as slaggy, pumiceous, glassy, compact, columnar; volcanic bombs, lapilli, sand, dust, etc.; (*b*) kinds of lava, both ancient and modern; (*c*) kinds ejected by the same volcano at different periods of eruption; (*d*) chemical products.

(2) Specimens showing contact phenomena and secondary minerals.

(3) The economy of volcanoes and allied phenomena, shown by chemical products, as sulphur and other sublimation products, pozzuolana, building stone (lavas and tuffs), travertines.

The most striking of the objects in this exhibit are the pumiceous (bread crust) bombs from Lipari; the stalactitic lavas and Pele's hair from the Hawaiian volcanoes; the large masses of obsidian and pumice from the Yellowstone Park and Mono Crater, and the basaltic columns from Rhenish Prussia (pl. 12, fig. 2).

THE YELLOWSTONE NATIONAL PARK EXHIBIT.

The Yellowstone National Park, situated in the extreme northwestern portion of Wyoming, comprises an area of 2,142,720 acres. The central portion is essentially a broad, elevated plateau between 7,000

and 8,500 feet above sea level. (See pl. 14.) In addition to the wonderful scenic effect consequent to these altitudes, the park owes much of its interest to the evidence of recent and dying volcanism, as displayed in its hot springs and geysers, lava flows, fossil forests, and associated phenomena. The collection shows by means of the relief map, specimens, and photographs, including transparencies in the windows, such examples of the park phenomena as lend themselves to display. The material has been acquired through many sources. The U. S. Geological Surveys, Supt. P. W. Norris, in 1881, and Secretary and Mrs. Walcott in 1915, collected a considerable part of the quartz groups and sinters. Of particular interest are the siliceous geyser cone and the large fungoid-shaped siliceous sinters, the basaltic column, silicified woods, and masses of quartz (sometimes amethystine) and chalcedony.

CONCRETIONS AND SEGREGATIONS.

The exhibit includes a series of more or less spherical bodies which owe their forms in part to physical and in part to chemical agencies. These are commonly known as concretions, though in many instances the word segregation is more nearly applicable. Indeed, in some instances neither term is strictly correct, since the concretionary structure is wholly simulated.

In the arrangement of the collection the following scheme of classification has been adopted:

I. Concretionary form due to crystallization from a molten magma. Examples, the concretionary or spherulitic granites from Finland and Sweden (pl. 15, fig. 2).

II. Concretionary form due to precipitation from solution, with or without crystallization. Examples, large septarian nodules and chert-concretions in limestone.

III. Concretionary form due to segregation of solid particles, with or without a cement or binding constituent. Examples, the clay concretions from the Connecticut River.

IV. Concretionary form due to weathering and cementation; secondary. Example, the concretions of ferruginous sand from Maryland.

V. Concretionary form due to local cementation of beds and subsequent weathering away of uncemented portions; pseudo-concretions. Examples, the large spherical sandstone forms from the Cannon Ball River.

VEINS AND DIKES.

The term vein is commonly applied to fractures in rock masses which have become filled with secondary minerals deposited from

solution, while the term dike refers to intrusions of igneous matter into like preexisting cavities, or fractures, in the older rocks. The distinction between the two is not always apparent inasmuch as it is impossible in all cases to distinguish between a condition of solution and igneous fluidity. The pegmatite intrusions mentioned later are good examples of this feature. Both veins and dikes usually possess length greatly in excess of breadth, and of the two the dikes are the much more important as geological bodies, but of less importance as bearers of interesting minerals and ores. Among the more interesting objects in this collection are the veins of abestiform serpentine from Thetford, Canada; the banded gold and silver-bearing vein from the Rico district, Colorado; the diabase dikes in granite from Norway, Me.; and the small filamentous dikes from a boulder at St. Elizabeth, Me., illustrating the extreme fluidity of the magma.

Contact metamorphism.—The intrusion of a quantity of molten material into older rock masses often brings about a small amount of change, called contact metamorphism. Various phases of this are shown in specimens of altered limestone ejected by the volcano of Vesuvius, and limestone crystallized at contact with a trap dike from Thomaston, Me.

Metasomatosi.—The form of metamorphism known as metasomatosi is illustrated in the series showing the derivation of serpentine from a lime-magnesian pyroxene from Montville, N. J. In the large mass shown, the gray core of pyroxene may be observed covered with a thin crust of serpentine and traversed by large and small veins of the same substance, the process having been arrested before completion. In some instances the calcium set free has crystallized out in the form of calcite of a white or blue-gray tint. The exteriors of many of the nodules are often grooved and striated like glacial boulders, owing to expansion and consequent crowding in the process of hydration.

ROCK WEATHERING AND SOIL FORMATION.

The processes involved in the breaking down of rock masses, and their reduction to the condition of soils, are in part physical, and in part chemical. The physical processes are chiefly those of expansion and contraction caused by heat and cold; the chemical largely those of solution and hydration from atmospheric waters. Other processes involving oxidation and formation of new compounds may go on conjointly, but with the exception of the first named the results are not of such a nature as to lend themselves readily to exhibition.

The following series show the various transition stages from rock to the pulverulent material, ordinarily designated soil: (1)

Granite gneiss, District of Columbia; (2) granite, Stone Mountain, Georgia; (3) nephelin syenites, Arkansas; (4) diorite from Virginia; (5) diabase from Massachusetts; (6) dolomite from South Dover, N. Y.; (7) limestone from Maryland and Virginia; and (8) slate from Maryland. Attention may be called to the ferruginous clay representing the ultimate products of decomposition of rocks of nearly every type regardless of original composition. A series of typical examples of the East Indian laterites is of interest in this connection. A series of pegmatites from Blanford, Mass., well illustrates the origin of kaolin through feldspathic decomposition. Characteristic boulders of exfoliation are shown in diabase from Massachusetts and Virginia. A strikingly peculiar form of weathering is displayed by a large block of siliceous conglomerate from Wise County, Va. The block consists of water-worn pebbles of white quartz embedded in a finer ground of compact siliceous sand. The block was taken from the immediate surface and wherever the quartz pebbles projected so as to expose them to the weather, it will be observed they are more or less corroded and in some cases entirely eaten away. Where the pebbles lie beneath the surface they have escaped corrosion. The cause of the phenomena is not apparent, but it is probably both physical and chemical in its nature.

Examples of unequal and uneven weathering due to inequalities in composition are shown in the schist traversed by small quartz veins from Rhode Island. The quartz being most refractory stands out in relief as the softer portions weather away. The eroding action of wind-blown sand is shown in beautifully polished "sand blasted" masses of quartzite from Minnesota, in the irregularly and sometimes grotesquely carved sandstone from various points in the West, the carved pebbles ("dreikante") from several sea beaches, and a window pane from a lighthouse at Nauset, Mass., etched by wind-blown sand during a storm of but a few hours.

Illustrative of special phases of weathering, attention may be called to the thin sheets of granite and porphyry flaked off from the main ledges through expansion and contraction caused by natural changes of temperature. The more striking examples are from Ellsmere Land and Mount Kineo, Me.

A large block of sandstone from Arkansas shows induration along joint planes due to a segregation of iron oxide, the oxidation being brought about by the percolation of water along the joints. The intervening material being robbed of its cementing constituent crumbles away under the influence of the weather, leaving the hollows.

GLACIERS AND GLACIAL PHENOMENA.

The general plan of this exhibit is as follows:

- I. Views illustrating living glaciers, icebergs, etc.
- II. Relief map of the United States showing the ice sheet of the glacial epoch in its lobate stage.
- III. Illustrations of glacial phenomena (pls. 12 and 13).
- IV. Specimens illustrative of the transporting and eroding power of glaciers.
- V. The possible economy of glaciers as illustrated in the utilization of glacial materials, clays, etc., and the stripping of rock masses of their decomposition products, rendering sound material available for quarrying.
- VI. The destructive effects of glaciation, as illustrated by fields covered by drift boulders and other glacial debris; the stripping of the surface of soils, and the burial of forests.

Among the drifted materials are boulders from various altitudes up to within a few feet of the summit on Mount Washington. These were all foreign to the mountain, and their presence fixes the minimum thickness of the ice sheet, at this point, at 6,000 feet.

There are other series of drift boulders of which the parent ledge is known, such as the peridotite from Cumberland, R. I., the jasper conglomerate from Leroy Township, Canada, and the native copper from Lake Superior. Examples of the latter are shown which were found as far to the south as Oxford, Ind., and of the conglomerate at various distances up to 600 miles from their source.

The relief map mentioned (pl. 14) which was originally prepared for the World's Columbian Exposition at Chicago in 1893, bears the following explanatory label:

MODEL OF THE UNITED STATES

showing the theoretical restoration of the Ancient Ice-sheet at the stage of the Glacial Period following the Main Silt Epoch. Constructed from data furnished by T. C. Chamberlin and associates of the U. S. Geological Survey; the outline of the ice follows the outer terminal moraine next north of the main silt deposits, and probably does not represent a strictly synchronous stage throughout, as later advances of the ice at some points overrode earlier ones, making it difficult to trace a perfectly synchronous line. The slope of the surface of the ice is based on an adaption of that of Greenland, as given by Nansen.

The scale of the model is 1 inch to 40 miles. It shows the correct curvature at sea level, and is a section of a globe 16½ feet in diameter; elevation and depression above and below sea level exaggerated five times.

THE MECHANICAL ACTION OF WAVES IN BREAKING DOWN ROCKY CLIFFS
AND THE FORMATION OF PEBBLES.

The exhibit begins with characteristic slabs of a schist with included quartz veins from the coast of Cape Elizabeth, Me. The continual hammering of the waves causes the schist to slowly disintegrate and fall to the foot of the cliff. The quartz veins being the hardest and toughest remain intact to the last, as shown in one of the larger specimens (36036). Once at the foot of the cliff, the fragments are alternately thrown upon the beach and dragged back into the sea by each successive wave and its return undertow, until gradually reduced to the pebble form. All stages in the process are shown, from the angular fragment as it fell from the cliff to the resultant oval pebbles. It will be observed that owing to the fissile nature of the schist (70056) its pebbles are always in the form of a greatly flattened oval, while those of the quartz (70055) are more nearly spherical. At the end of the series is a coarse sand composed of fragments of schist, quartz, and shells, and which was obtained at low tide further out from the shore.

This exhibit is accompanied by one designed to show the manner in which sedimentary materials are derived through the breaking down of rock masses through the ordinary processes of weathering. For this purpose the granitic rock of Rock Creek Valley in Washington has been selected. The exhibit begins with (1) a sample of fresh granite, (2) one of partially decomposed granite, and (3) a jar of the material decomposed to the condition of a coarse granitic soil. The eight succeeding jars contain an amount of soil equal to that in the large jar, which has been separated into portions of fairly uniform sizes by sifting and washing. The individual labels give the percentage amounts of the various portions as compared with that in the larger jar.

Attention is called to the fact that, by the consolidation of such sediments, there might be formed a series of elastic rocks ranging from coarse to fine, which would be classified as conglomerates and breccias, coarse and fine sandstones, shales and argillites.

FAULTS, FOLDS, ETC.

Effects of earth stresses.—Rock masses subjected to great compressive force or tension are sometimes distorted, crushed, or faulted in a very striking manner and on a scale such as can not be shown other than by photographs or other form of illustration. Frequently, however, blocks of a size suitable to museum exhibition are found. Such are exhibited here. Attention need be called to the folded jaspery hematite, (Spec. No. 70266), from Ishpeming, Mich., and

the finely contorted shale (Nos. 83862 and 75535) from Maryland. In cases where the earth stresses have been sufficiently great, or the rocks through composition or lack of load were too brittle, crushing and fracturing with more or less displacement ensued, producing what are known as faults. In some instances the amount of displacement was so slight that examples can be shown by specimens as in the faulted sandstone from South Dakota or the gneiss from Montana. The slate showing cleavage and faulting (fig. 3, pl. 12) is especially instructive.

METEORITES.

The collection of meteorites, occupying special bases and cases in the center and on the west side of the hall, comprise the C. U. Shepard collection, numbering 234 falls and finds, and that of the Museum proper numbering 407 falls and finds. The collections partially duplicate one another, but collectively represent 496 independent falls and finds.

Below is a transcript of the general label accompanying the collection:

METEORITES: SKY STONES.

The term meteorite is applied to those bodies of stone or metal which occasionally fall to the earth from space. Such are composed sometimes almost wholly of metal or, again, of stony matter, with many intergradations. The metal is mainly iron alloyed with nickel and cobalt; the stony matter mainly olivine and pyroxene with more rarely feldspar and free silica in the form known as *asmanite*. Other minerals in minor proportions are the phosphide of iron, *schreibersite* (*rhodite*); the oxide of iron and chromium, *chromite*; the sulphides of iron, *troilite* or *pyrrhotite*; the chloride of iron, *lawrencite*; the last named, on account of its ready oxidation in a moist atmosphere, producing the rusty appearance and even disintegration of many meteorites and necessitating their preservation in a petroleum distillate or other medium. According to the proportional quantities of the metallic and silicate constituents, the meteorites fall into three general groups, with intermediate gradations. These three are (I) Meteoric irons, or *siderites*; (II) meteoric stony irons, or *siderolites*; and (III) meteoric stones, or *aerolites*. Subdivisions of these groups are based on minor distinctions.

The exhibition begins with an introductory series showing each of the principal types, and examples of etched irons with *Widmanstatten* figures and other markings; there are also separations of *troilite* nodules, *chondrules*, *schreibersite*, *cohenite*, carbon, etc. Through the center of the hall are displayed on special bases (pl. 15, fig. 1) the larger metallic masses of Tucson, Casas Grandes, Canon Diablo, and Owens Valley, while in special cases between the columns are the

systematic collections arranged according to the generally accepted classification. Among the stony irons (Pallasites) attention may be called to that from Mount Vernon, Ky., and of the stones, the coarse breccia from Cumberland Falls in the same State and to the chondritic types from Allegan, Mich., and New Concord, Ohio.²

In the introductory cases are included also examples of the so-called tektites (billitonites, australites, moldavites, etc.) considered by some as of probably meteoric origin.

THE GRANITE PEGMATITES AND THEIR ASSOCIATED MINERALS.

The peculiar structural phase of granite known as pegmatite or sometimes graphic granite, is of both great scientific and economic interest on account of the minerals it carries, either accessory or as essential constituents. The two essential constituents, feldspar and mica, are of greatest economic importance. The accessory gem minerals are beryls and tourmalines, but numerous other interesting forms occur making the pegmatites a favorite hunting ground for the mineral collector. The collections exhibited are designed to show their general character and mineral associations.

The eastern pegmatites, and particularly those of Maine, are noted for their green tourmalines, aquamarines, and blue apatites. The Californian pegmatites owe their great popular interest to the two gem minerals, kunzite and pink tourmaline. These occur in pockets or cavities, filled with other fragmental and decomposed material. As arranged a quantity of clastic material is shown as taken from the ground, and then the same amount separated into its component parts, of quartz fragments, feldspar, kunzite, tourmaline, etc. Both of these collections are described in detail in the catalogue of the Isaac Lea collections of gems and precious stones (Bull. 118, U. S. N. M.) and need no further consideration here.

MISCELLANEOUS AND MINOR EXHIBITS.

Imitative forms.—The forms assumed by inorganic matter sometimes so closely resemble those that are organic or of artificial origin as to be quite misleading, or at least create a feeling of doubt in the minds of those who have not given the subject special attention. The collection here brought together is designed to show some of these forms and to explain, so far as possible, their true nature. The dendritic deposits of manganese oxide so often mistaken for "fossil moss" and ferns, vesicular furnace slag supposed to be wasp nests, the coral thought to be honeycomb, and other more or less imitative forms are here shown.

² For details of this collection, up to date of publication. see Bull. 94, U. S. Nat. Museum, 1916.

Effects of lightning.—Lightning striking in loose sand often so fuses the material in the immediate vicinity of its path as to form irregular tubes rough on the outside, but smooth and glassy within. These are called fulgurites; they may vary from a few inches to many feet in length, but are too brittle for preservation in any but short sections. Lightning striking on firm rock may melt it on the immediate surface or even bore small holes entirely through it, as in the samples from the Elk Mountains of Colorado and Mount Ararat, Armenia.

The transporting power of wind and ocean currents.—This is shown by a series of jars containing wind-transported material like volcanic dust from Krakatoa and other localities, and loess deposits from the United States and China.

Mud and ripple marks.—Mud and ripple markings made during deposition of sediment in shallow waters, and mud cracks due to shrinkage on drying are shown on large slabs of sandstone and quartzite from Ohio, New York, and Pennsylvania.

Sedimentation on sea bottoms.—This is shown by samples of dredgings from various oceanic depths. Of particular interest is a series of separations into their component parts of soundings in the Pacific Ocean by the U. S. steamship *Nero*.

Collection illustrating the geology and minerology of the District of Columbia.—The areas occupied by the various geological formations, crystalline and fragmental, are shown by a relief map. The region, as a whole, is very poor in rock types, minerals, or fossils. What few minerals are found occur almost wholly in the crystalline rocks of the northwest section. The collection shows all the forms thus far discovered.

HISTORY OF AMERICAN GEOLOGY.

In the aisle at the end of the hall are two flat cases containing collections relating to the history of American geology, and including portraits of the early workers and copies of their published works.

Reserve or study series.—During the work of the various governmental surveys, and to a less extent State and private surveys, there have accumulated and been assigned for preservation in the National Museum a very large number of collections of rocks and ores which are grouped in part under kinds, but to a large extent preserved as collections representing the studies of particular areas, the results of which have been published in detail. These are not on exhibition, but constitute the reserve or study series referred to elsewhere.

The following list includes some of the more important of these collections:

Anthracite-Crested Butte quadrangle, Colorado, Folio 9, U. S. Geol. Survey.
Apishapa quadrangle, Colorado, Folio 186, U. S. Geol. Survey.

- Aspen, Colo., Monograph 31, U. S. Geol. Survey.
- Austin quadrangle, Texas, Folio 76, U. S. Geol. Survey.
- Bear Paw Mountains, Mont., *American Journal Science*, 1896.
- Bentley district, Arizona, Bull. 580-D, U. S. Geol. Survey.
- Bidwell Bar quadrangle, California, Folio 43, U. S. Geol. Survey.
- Big Belt Mountains, Mont.
- Bighorn Mountains, Wyo., U. S. Geol. Survey, Prof. Paper 51.
- Big Trees quadrangle, California, Folio 51, U. S. Geol. Survey.
- Bisbee quadrangle, Arizona, Folio 112, U. S. Geol. Survey.
- Bitterroot Mountains, Idaho, U. S. Geol. Survey, Prof. Paper 27.
- Blue Mountains, Oreg., 22nd Ann. Rep. U. S. Geol. Survey, pt. 2.
- Bohemia district, Oregon, 20th Annual Report U. S. Geol. Survey, part 3.
- Boise quadrangle, Idaho, Folio 45, U. S. Geol. Survey.
- Boston Basin, Mass., *Geol. of Boston Basin*, 1893.
- Boulder, Mont., 21st Annual Report, U. S. Geol. Survey, part 2.
- Bradshaw Mountains, quadrangle, Arizona, Folio 126, U. S. Geol. Survey.
- Breckenridge district, Colorado, U. S. Geol. Survey, Prof. Paper No. 75.
- Bullfrog district, Nevada, Bull. U. S. Geol. Survey, No. 407.
- Butte district, Montana, Folio 38, U. S. Geol. Survey.
- Castle Mountain, Mont., Bull. 139, U. S. Geol. Survey.
- Central City, Colo.
- Chico area, California, 17th Annual Report, U. S. Geol. Survey, part 1.
- Cid mining district, North Carolina, Bull. 22, N. C. Geol. Survey.
- Cinnabar deposits, Idaho and Montana, Bull. 384, U. S. Geol. Survey.
- Clifton quadrangle, Arizona, Folio 129, U. S. Geol. Survey.
- Coeur d'Alene district, Idaho, Prof. Paper 82, U. S. Geol. Survey.
- Colorado Springs, quadrangle, Colorado, Folio 263, U. S. Geol. Survey.
- Colville Reservation, Wash., Bull. 677, U. S. Geol. Survey.
- Contact and Jarbidge districts, Nevada, Bull. 497, U. S. Geol. Survey.
- Crater Lake, Oreg., Prof. Paper 3, U. S. Geol. Survey.
- Cripple Creek, Colo., 16th Annual Report, U. S. Geol. Survey and Prof. Paper 54.
- Custer County, Colo., 17th Annual Report, U. S. Geol. Survey.
- Dan River coal field, North Carolina, Bull. 471-B, U. S. Geol. Survey.
- Darwin district, California, Bull. 580-A, U. S. Geol. Survey.
- Davidson County, N. C., (see Cid Mining Dist.).
- Delamar, Idaho (see Silver City).
- Deming quadrangle, New Mexico, Folio 207, U. S. Geol. Survey.
- Denver Basin, Colo., Monograph 27, U. S. Geol. Survey.
- Dillon, Mont., Bull. 574, U. S. Geol. Survey.
- Downieville quadrangle, California, Folio 37, U. S. Geol. Survey.
- Eastport quadrangle, Maine, Folio 192, U. S. Geol. Survey.
- Elkhorn district, Montana, 22d Annual Report, U. S. Geol. Survey.
- Ellensburg quadrangle, Washington, Folio 86, U. S. Geol. Survey.
- Elkhay quadrangle, Georgia, North Carolina, Tennessee, Folio 187, U. S. Geol. Survey.
- Elliott County, Ky., Bull. 38, U. S. Geol. Survey.
- Elliston phosphate field, Montana.
- Encampment Special, Wyo., Prof. Paper 25, U. S. Geol. Survey.
- Engineer Mountain quadrangle, Colorado, Folio 171, U. S. Geol. Survey.
- Eureka district, Nevada, Monograph 20 and 3d Annual Report, U. S. Geol. Survey.
- Flathead Indian Reservation, Mont.
- Fort Benton quadrangle, Montana, Folio 55, U. S. Geol. Survey.

- Fortieth parallel Survey, vol. 6.
 Georgetown, Colo., Prof. Paper, U. S. Geol. Survey No. 63.
 Gilpin and adjacent portions of Clear Creek and Boulder Counties, Colo., Prof. Paper 94, U. S. Geol. Survey.
 Globe quadrangle, Arizona, Folio 111, U. S. Geol. Survey.
 Golden Arrow and Clifford districts, Nevada, Bull. 640-F, U. S. Geol. Survey.
 Goldfield, Nev., Prof. Paper 66, U. S. Geol. Survey.
 Grass Valley Special, Calif., Folio 29, U. S. Geol. Survey.
 Hardscrabble mining district, Colorado, Bull. 580-C, U. S. Geol. Survey.
 Hartville iron ores, Wyoming, Bull. 315, U. S. Geol. Survey.
 Hawaiian Islands, Prof. Paper 88, U. S. Geol. Survey.
 Hayden Hill, Calif., Bull. 594, U. S. Geol. Survey.
 Helena mining district, Montana, Bull. 527, U. S. Geol. Survey.
 High Grade district, California, Bull. 594, U. S. Geol. Survey.
 Highwood Mountains, Mont., Bull. Geol. Survey of America, vol. 6.
 Holyoke Reservation, Mass., Folio 59, U. S. Geol. Survey.
 Independence quadrangle, Kansas, Folio 159, U. S. Geol. Survey.
 Indian Valley, Calif., Bull. 260, U. S. Geol. Survey.
 Inyo Range, Calif., Prof. Paper 110, U. S. Geol. Survey.
 Iron Mountains district, Missouri.
 Jackson quadrangle, California, Folio 11.
 Joplin and Boone Terre, Mo., Folio 148, U. S. Geol. Survey.
 Judith Mountains, Mont., 18th Annual Report, U. S. Geol. Survey, part 3.
 Kenova quadrangle, Kentucky, Folio 189, U. S. Geol. Survey.
 Klamath Indian Reservation, Oreg.
 Lake Champlain, Vt., Bull., 107, U. S. Geol. Survey.
 La Plata quadrangle, Colorado, Folio 60, U. S. Geol. Survey.
 Leadville, Colo., Monograph 12.
 Leucite Hills, Wyo., American Jour. Science, 1897.
 Little Belt Mountains quadrangle, Montana, Folio 56, U. S. Geol. Survey.
 Little Rocky Mountains, Mont., Jour. Geology, 1896.
 Livingston quadrangle, Montana, Folio 1, U. S. Geol. Survey.
 Llano-Burnet quadrangle, Texas, Folio 183, U. S. Geol. Survey.
 Marysville, Mont., Prof. Paper 57, U. S. Geol. Survey.
 Miners Basin and Wilson Mesa, Utah, Bull. 530, U. S. Geol. Survey.
 Mohave County, Ariz., Bull. 397, U. S. Geol. Survey.
 Mount Greylock, Mass., Monograph 23, U. S. Geol. Survey.
 Mount Stuart Quadrangle, Washington, Folio 106, U. S. Geol. Survey.
 Mount Taylor, N. Mex., 6th Annual Report U. S. Geol. Survey.
 Nampa, Idaho, quadrangle, Folio 103, U. S. Geol. Survey.
 National district, Nevada, Bull. 601, U. S. Geol. Survey.
 Needle Mountains quadrangle, Colorado, Folio 131, U. S. Geol. Survey.
 Nevada City Special, California, Folio 29, U. S. Geol. Survey.
 Northeastern and Republic mining districts, quadrangle, Washington, Bull. 550
 U. S. Geol. Survey.
 Ouray quadrangle, Colorado, Folio 153, U. S. Geol. Survey.
 Park City, Utah, Prof. Paper 77, U. S. Geol. Survey.
 Pearl district, Colorado, Prof. Paper 25, U. S. Geol. Survey.
 Penobscot Bay quadrangle, Maine, Folio 149, U. S. Geol. Survey.
 Philipsburg quadrangle, Montana, Folio 196, U. S. Geol. Survey.
 Pikes Peak and Cripple Creek, Colo., Folio 7, U. S. Geol. Survey.
 Preston, Conn., Bull. 492, U. S. Geol. Survey.
 Pueblo quadrangle, Colo., Folio 36, U. S. Geol. Survey.

Quicksilver deposits, Nevada, Bull. 620-D, U. S. Geol. Survey.
Rabbit Hole, Nev., Bull. 225, U. S. Geol. Survey.
Ray and Miami copper districts, Arizona, Prof. Paper 115, U. S. Geol. Survey.
Redding quadrangle, California, Folio 138, U. S. Geol. Survey.
Rico quadrangle, Colorado, Folio 130, U. S. Geol. Survey.
Rio Grande Region, New Mexico, Water Res. Paper, 188, U. S. Geol. Survey.
Rochester mining district, Nevada, Bull. 580-M, U. S. Geol. Survey.
Rockland quadrangle, Maine, Folio 158, U. S. Geol. Survey.
Roseburg quadrangle, Oregon, Folio 49, U. S. Geol. Survey.
Ruby Hill, Nev., Monograph 7, U. S. Geol. Survey.
San Francisco and adjacent districts, Utah, Prof. Paper 80, U. S. Geol. Survey.
San Luis Quadrangle, California, Folio 101, U. S. Geol. Survey.
Santa Cruz Quadrangle, California, Folio 163, U. S. Geol. Survey.
Santa Rita and Patagonia Mountains, Ariz., Bull. 582, U. S. Geol. Survey.
Searles Lake, Calif., Bull. 580-L, U. S. Geol. Survey.
Silver City, quadrangle, Idaho, Folio 104, U. S. Geol. Survey.
Silver Cliff-Rosita, Colo., 17th Annual Report, U. S. Geol. Survey.
Silver Peak, Nev., Prof. Paper 50, U. S. Geol. Survey.
Silverton quadrangle, Colorado, Folio 120, U. S. Geol. Survey.
Snake River Valley, Idaho.
Snoqualmie quadrangle, Washington, Folio 139, U. S. Geol. Survey.
Sonora quadrangle, Washington, Folio 41, U. S. Geol. Survey.
South Mountain, Pa., Bull. 136, U. S. Geol. Survey.
Southern Sierra Escarpment, Calif., Prof. Paper 110, U. S. Geol. Survey.
Sugar Loaf district, Colorado.
Tacoma quadrangle, Washington, Folio 54, U. S. Geol. Survey.
Taylorsville Region, California, Bull. 353, U. S. Geol. Survey.
Telluride quadrangle, Colorado, Folio 57, U. S. Geol. Survey.
Ten Mile district, Colo., Folio 48, U. S. Geol. Survey.
Tewan Mountains, N. Mex., Bull. 66, U. S. Geol. Survey.
Three Forks quadrangle, Montana, Folio 24, U. S. Geol. Survey.
Tintic district, Utah, Folio 65 and Prof. Paper 107, U. S. Geol. Survey.
Tonopah, Nev., Prof. Paper 104, U. S. Geol. Survey.
Uvalde quadrangle, Texas, Folio 64, U. S. Geol. Survey.
Virgilia district, Virginia, Proc. U. S. Nat. Mus., vol. 40.
Washoe district, Nevada, Monograph 3, U. S. Geol. Survey.
White Mesa district, Arizona, Bull. 540, U. S. Geol. Survey.
Wichita Mountains, Okla.
Winters (Hess) district, California, Bull. 594, U. S. Geol. Survey.
Yellowstone National Park, Wyo., Monograph 32, U. S. Geol. Survey.
Yerington district, Nevada, Prof. Paper 114, U. S. Geol. Survey.
Yuma County, Ariz., Bull. 451, U. S. Geol. Survey.

In addition to the above there is a large collection of rocks and ores from world-wide sources which are classified by *kinds*, rather than locality.

DIVISION OF MINERALOGY.

EAST WING, SECOND FLOOR, SOUTH SIDE.

Entering the hall from the rotunda on the west, the visitor finds upon his immediate right an "Introductory Series" consisting of minerals selected to show the physical properties of color, hardness,

crystallization, and structure, the series showing perfection of crystalline form being as yet incomplete. Beyond this is a small upright case containing examples of the nongaseous elements that occur in nature, free or uncombined. Upon the left is a row of 14 cases (known as American cases) in which are installed a systematic series of minerals comprising upwards of 3,500 specimens from all parts of the world, arranged according to the system prevailing among mineralogists. It is difficult among so many to select any particular specimens for especial reference. On account of their rarity and crystal development the large scheelite from Ryndo, Korea, the gift of Mr. J. Morgan Clements, and the cinnabar from Hunan Province, China, the gift of United States Consul N. T. Johnson are worthy of mention, though to the public at large the beautiful series of California tourmalines, the Brazilian and North Carolina emeralds, the large (1,022 pounds) beryl from Grafton, N. H., and the large cluster of Brazilian amethysts are doubtless more attractive (pl. 17, fig. 2).

Among the rare, but inconspicuous objects are the only specimens known of crystallized turquoise, two of the finest known specimens of the rare mineral hodgkinsonite, a series of exceptionally fine, crystal groups of ferberite, and a cluster of the largest known colemanites.

On the south side of the hall (pl. 16, fig. 1) are 9 floor upright cases in which are arranged materials of the same nature as those on the north side, but not systematically classified. They are selected mainly on account of their size and beauty, and special reference may be made to the fluorites from St. Lawrence County, N. Y., and Cumberland, England; two cases showing the forms of calcium carbonate occurring in nature, including the large clusters and twin forms of calcite from the lead mines of Missouri; two similar cases showing the varieties of quartz or silica; one case of zeolites from the trap rocks of New Jersey, and one of numerous ornaments cut from various kinds of material as described in the catalogue of gems and precious stones. Two flat cases contain an historically interesting collection assembled by Prof. C. U. Shepard, one of America's pioneer mineralogists. This is particularly rich in rutiles from Graves Mountain, Ga. At the eastern end of the hall are large masses of the copper carbonates, azurite and malachite, from the copper mining regions of Arizona and Russia.

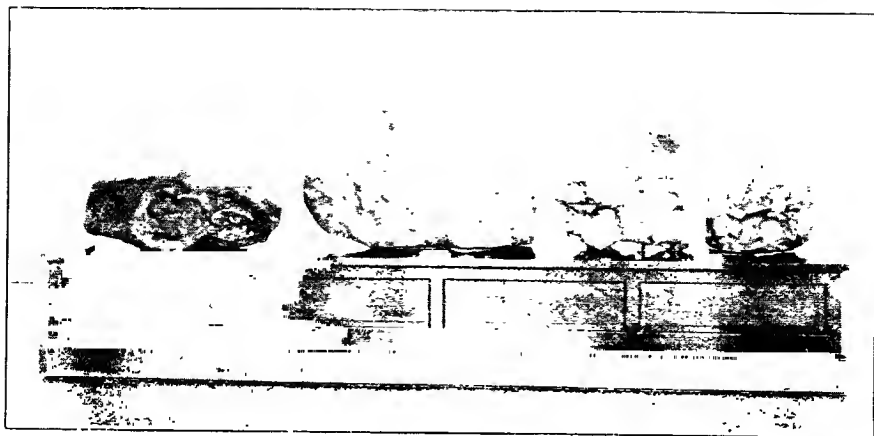
While by no means the largest or finest of the numerous mineral collections of the country, the Museum collection is unusual in the number of type specimens it contains (upwards of 100) i. e., the actual materials upon the study and analysis of which new species have been founded.

THE GEM COLLECTION.

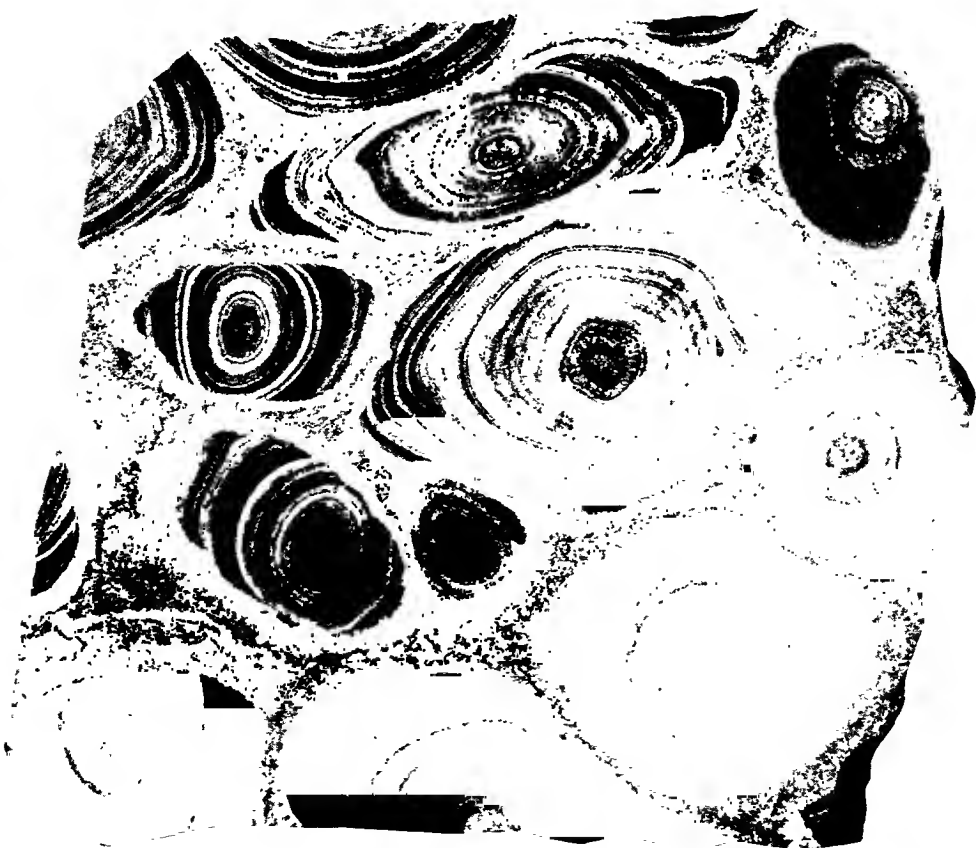
In the row of flat topped cases extending through the center of the hall is exhibited a collection of cut stones and gems known as the Isaac Lea collection. The history of this collection is as follows: In 1884, Prof. F. W. Clarke, at the time honorary curator of the Division of Mineralogy, prepared an exhibition of American precious stones as a part of the United States National Museum's contribution to the New Orleans Exposition. The same collection was displayed at the Cincinnati Exposition the year following, after which it was returned to Washington and incorporated in the mineral collection of the Museum. In 1891, the collection was greatly augmented by purchases from the estate of Dr. Jos. Leidy, of Philadelphia, and exhibited at the World's Columbian Exposition in Chicago in 1893, when it was returned once more to Washington. In 1894, Mrs. Frances Lea Chamberlain bequeathed to the Museum a collection of precious stones which had been made by her father, Dr. Isaac Lea. Later, in 1897, her husband, Dr. L. T. Chamberlain, became honorary curator of the collection and added a large number of desirable specimens. On his death he bequeathed a sum of money the income from which is used for its further increase.

In addition to the above sources many specimens have been received as gifts from individuals and transfers from the United States Geological Survey. These various collections have been combined and are now exhibited as the Isaac Lea collection, although the individual stones are differentiated by labels. The exhibition as above noted is comprised in a row of table cases down the center of the hall (see pl. 16, fig. 1). At the west end of this row immediately to the right of the entrance to the hall stands a large group of amethyst crystals from Brazil. In the table cases fronting the windows on the south side of the hall are other series illustrating the properties of precious stones, their appearance in the rough as contrasted with the cut form; gem minerals in the matrix or as occurring in nature, and artificial and imitation stones. Finally, an upright case between the windows at the center of the hall contains many semiprecious stones—that is, stones used in the manufacture of small ornaments, rather than for personal adornment.

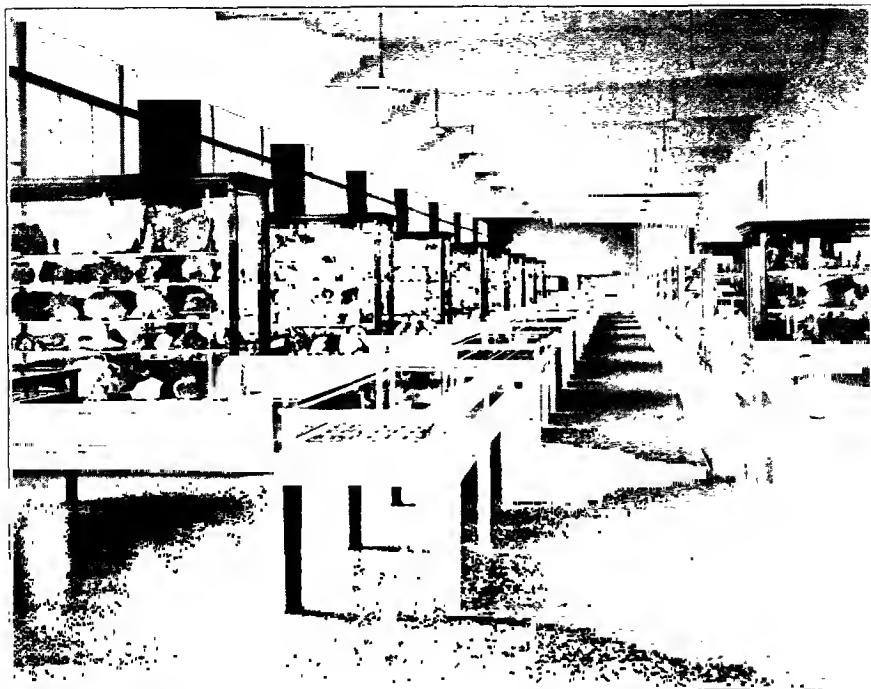
The collection now comprises some 4,000 individual stones, including not only those used for personal adornment, but as well such as are used in the smaller works of art and utilitarian purposes. Especial attention may be called to the cases of opals, both cut and in the rough. Among the individual cut stones mention may be made of the 57.5-carat green tourmaline from Maine, the unique 61-carat yellow orthoclase from Madagascar, the blue zircons from Australia; the 40 and 47 carat aqua marines from Connecticut and Siberia; the



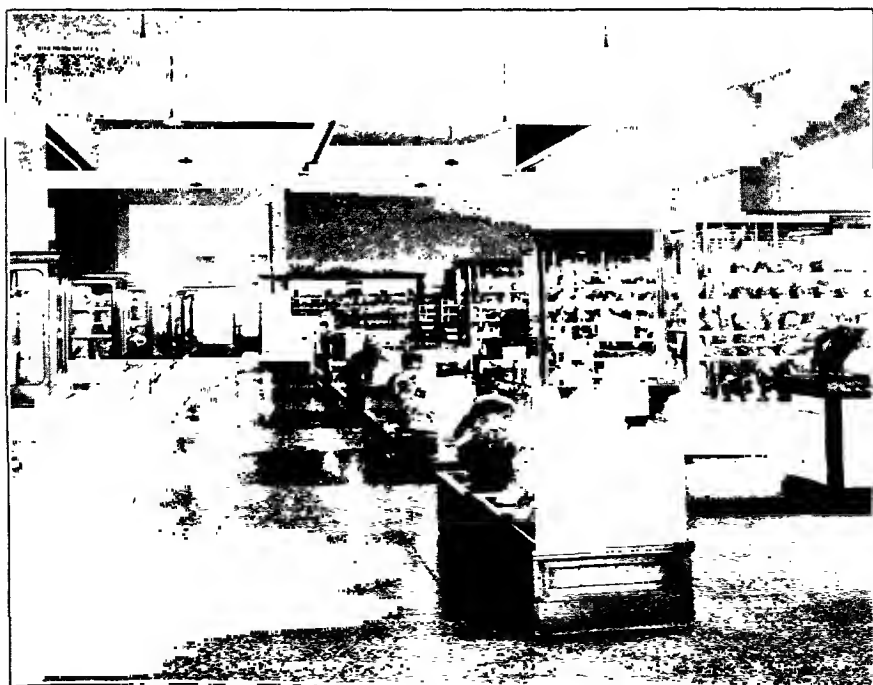
1. GROUP OF METEORITES.



2. SPHEROIDAL GRANITE.



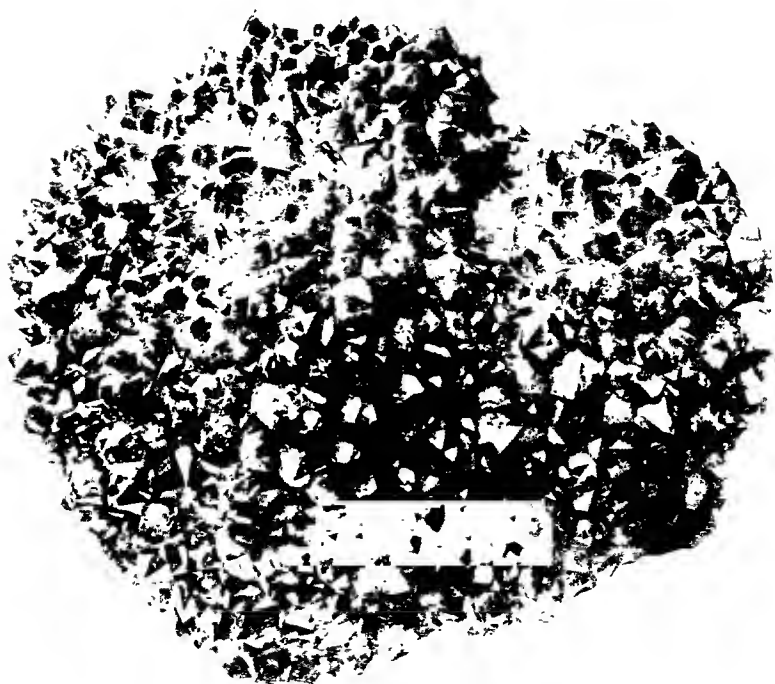
1. EAST WING, SECOND FLOOR, SOUTH SIDE. MINERAL HALL.



2. EAST WING, SECOND FLOOR, EAST END. ECONOMIC GEOLOGY.



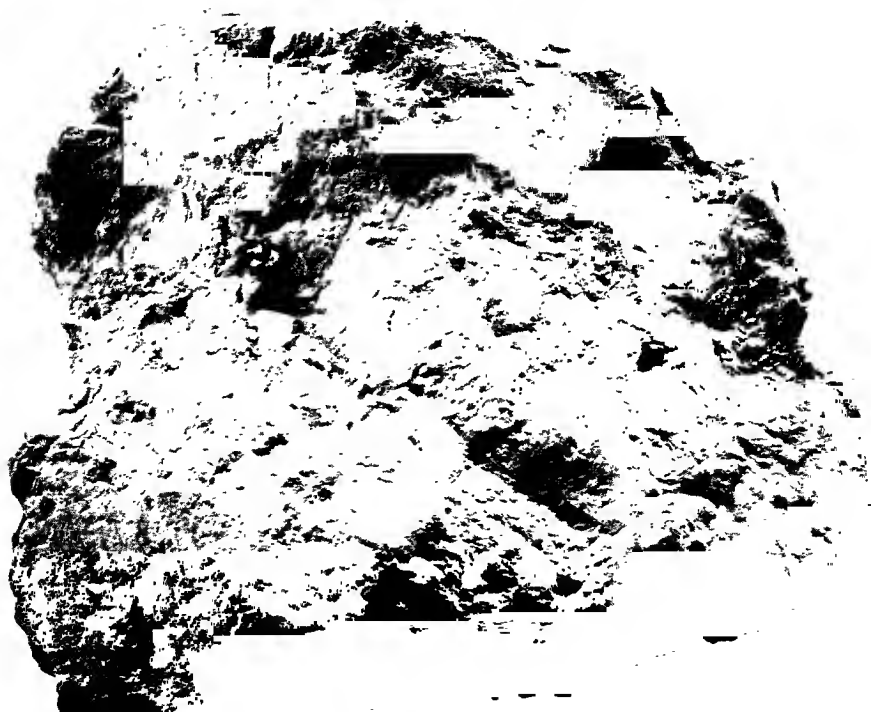
1. CRYSTALLIZED GOLD.



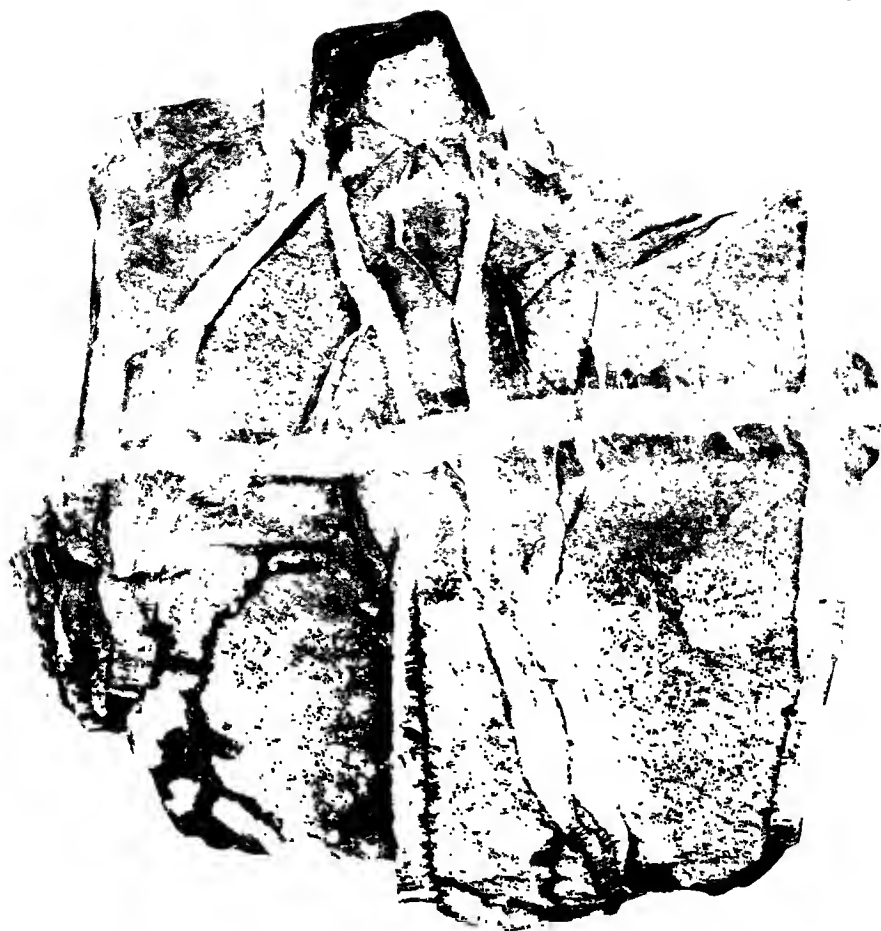
2. CLUSTER OF AMETHYSTINE QUARTZ.



1. PLATINUM NUGGET.



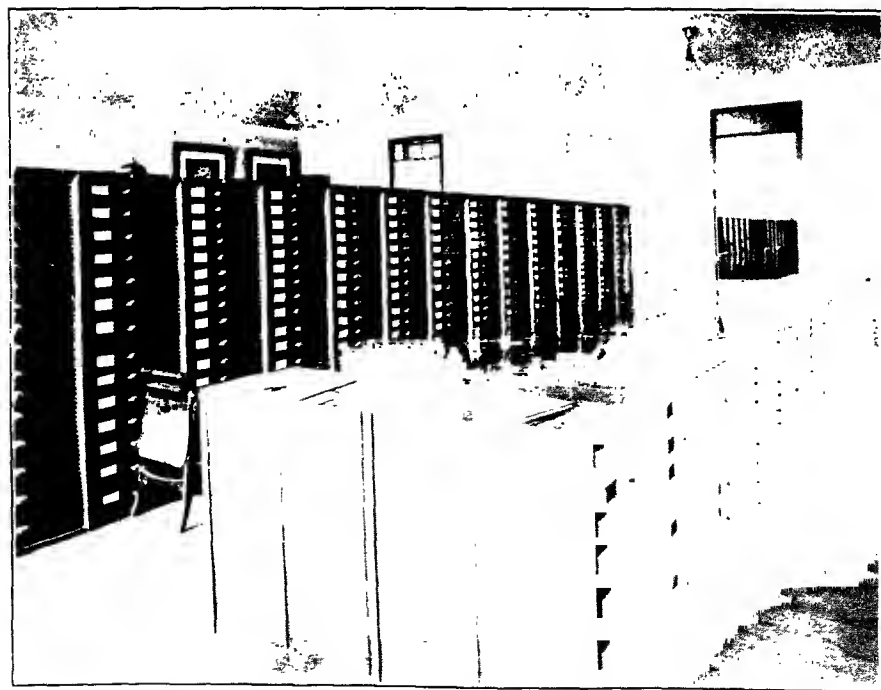
2. ONTONAGON COPPER BOWLDER.



VEINS OF ASBESTIFORM SERPENTINE IN MASSIVE SERPENTINE.



1. EAST WING, SECOND FLOOR, NORTH SIDE. NONMETALLICS AND BUILDING STONES.



2. STOREROOM FOR STUDY COLLECTIONS.

50-carat white topaz from Japan, the 155-carat blue topaz from the Russian Urals, and a series of uncut diamonds from Arkansas, selected to show the natural crystal forms and the variation in color.

It may be added that in building up the collection an attempt has been made to show the possibilities of commonplace material; that there is a goodly number of stones, in themselves of little intrinsic value, which when properly cut and mounted are not merely beautiful, but have the additional value of being out of the line of the usual material sold in shops. In this connection particular attention may be called to the cabochons of silicified wood, obsidian, epidotic granite (unakite), and green feldspar (amazonstone).³

SECTION OF ECONOMIC GEOLOGY.

EAST WING, SECOND FLOOR, EAST END AND NORTH SIDE.

The mineral collection merges at the east end of the hall into that of economic geology, under which name are comprised only those minerals which have some economic value, either in their natural condition or as sources from which valuable substances may be derived. These collections are divided into two series, metallic and non-metallic. The metallic begins with a flat top case containing exceptionally fine crystalline aggregates of gold and silver (pl. 17. fig. 1). Of historical interest in this case is a minute flake of gold, the identical piece found by John Marshall in the mill race at Sutter's Fort in 1848, and by him hammered out to determine its nature. The following is a transcript of a letter accompanying it and which guarantees its authenticity.

SAN FRANCISCO, *August 23, 1848.*

This paper contains the first piece of gold ever discovered in the northern part of Upper California. It was found in February, 1848, by James W. Marshall in the race of Capt. Jno. A. Sutter's sawmill about 45 miles from Sutter's Fort, on the south branch of the American Fork. It was beaten out with a hammer by Mr. Marshall, to test its malleability.

It is presented to the National Institute, Washington, D. C.

J. L. FOLSOM,

Captain, Assistant Quartermaster.

Among other objects of unusual interest are a cube of iron pyrites carrying crystallized gold and galena from near Juneau, Alaska; several clusters and groups of gold and silver crystals, and an unusually large (444 grams) waterworn platinum nugget from Nijni Tagilsk, Russia (pl. 18. fig. 1). Immediately adjacent to this case is the large mass of native copper, weighing approximately 3,000 pounds, brought in 1873 from the Lake Superior region (pl. 18. fig. 2). and large pieces of amygdaloid and breccia, showing impreg-

³ For details of this collection, see Bulletin 118, U. S. National Museum, 1922.

nations of the same metal. In a special case at this end of the hall is also exhibited a series of radio-active minerals and radium ores accompanied by a portrait and autograph of Mme. Curie. The exceptionally large and beautiful yellow masses of carnotite from Naturita, Colo., were secured for the Museum from Mr. J. I. Mullen, by Mr. F. L. Hess. This series is augmented by two large sections of fossil logs impregnated with carnotite from Thompson Springs, Utah.

The systematic metallic series begins in a row of floor upright cases at the east end of the hall (pl. 16, fig. 2). The collections are arranged in the following order: Ores of gold, silver, silver lead, zinc, copper, platinum, antimony, minor metals (including arsenic, bismuth, iridosmine, and cadmium), iron, mercury, aluminum, nickel, manganese, and the minor metals used in steel manufacture (as tungsten, vanadium, titanium, and molybdenum). Among the gold ores are samples of the rich gold-bearing gravel from Dutch Flat, Placer County, Calif., a large series of placer golds from Alaska, New Zealand, and miscellaneous localities within the limits of the United States. Among the silver ores, attention may be called to the nugget of native silver, weighing 448 ounces, from near Globe, Ariz., and the dendritic silvers from the region of Lake Superior. Also large ore masses showing full width of the veins from the Reese River district, Nevada, and the Enterprise mine, Rico district, Dolores County, Colo. As with other metals, the exhibit is accompanied with a carefully selected series showing the metalliferous minerals in their purity, and the ore as mined in which the mineral is often so thoroughly disguised as to be not recognizable.

The silver lead ores—mainly galena—from world-wide sources are selected to show all possible variations from the original native sulphide through anglesite, cerusite, and impure ferruginous varieties.

The ores of lead, which are mainly galena, are of the same general type.

Ores of zinc are largely sulphides and their alteration products, smithsonite and calamine. These are shown in all their varieties. The unique deposit of silicate and oxide ores at Franklin, N. J., is illustrated by fine large specimens showing zincite, willemite, and franklinite, with their numerous accessories. As an adjunct to this are two desk-top cases in front of the window containing selected series of zinc ores and associated minerals and rocks from the Franklin furnace and southwest Missouri regions.

Ores of tin are shown from all the principal tin regions of the world. These comprise a large series of the Straits tins and also of those from the historical Cornwall mines, and stream tins and vein ores from the numerous nonproducing localities of the United States,

including Virginia, North Carolina, South Dakota, and California. Of historical interest is a small bar of metallic tin smelted in 1840 from tin ore in Jackson, N. H., and a mass of block tin, weighing 70 pounds, smelted from the San Jacinto ores in California. This bears the following legend, which is of historical interest:

For Hon. Thos. S. Wilson,
Commissioner of the General Land Office.
Tin from the mines of the San Jacinto Tin Co.,
San Bernardino Co., California, U. S. A.
Office of Company, San Francisco, Mch., 1870.

The collection is particularly rich in the newly exploited Bolivian ores, including the somewhat rare form *cylindrite*, which have been secured for the Museum through the cooperation of Mr. F. L. Hess, of the U. S. Geological Survey.

The commercially workable copper ores are mainly in the form of chalcopyrite, bornite, chalcocite, and covellite, or their numerous alteration products—malachite and azurite. As with the other series these collections contain masses selected to show the pure mineral as well as in the gangue as ordinarily mined.

The ores of antimony are primarily the sulphide stibnite, though occurring sometimes native, as in the mass from Kern County, Calif. Of particular interest is the crystallized stibnite from Japan.

Ores of mercury are nearly altogether of the sulphide type cinnabar. The collection is particularly rich in samples from the Pacific coast, but contains also specimens from all important regions of the world.

The ores of aluminum are primarily beauxite, the hydrous impure oxide. This mineral is shown by samples from Georgia and Arkansas in the United States, as well as from the original locality Beaux, in France, and also from British Guiana. Cryolite, the fluoride of aluminum and calcium from Greenland, is shown in its typical forms. Corundum, the oxide of aluminum, is included, although not ordinarily considered an ore of the metal.

Nickel and cobalt, although widespread, rarely occur in quantities sufficient to be of economic importance. The main bodies of workable ore to-day are Canadian, where the nickel mineral is polydymite associated with pyrrhotite, and New Caledonia, in which the ores are a secondary product known under the names of garnierite and noumeite. There are shown also as of historical interest examples of the sulphide ore from the now abandoned mines at Lancaster County, Pa., the cobalt ore chathamite from the original locality at Chatham, Conn., and the rarer forms of ore, such as smaltite, niccolite and their oxidation products from other sources. An adjunct to this collection is shown in the desk-top case against the window. This includes a selected series of the nickel-copper ores and their associ-

ated rocks from the Sudbury district, Ontario, and also one of the cobalt nickel ores from Cobalt, Canada.

The principal ores of manganese are the oxides, of which there are numerous forms difficult to distinguish by the naked eye. The principal ones are psilomelane, which sometimes occurs in interesting botryoidal forms, and pyrolusite; more rarely manganosite, hausmanite, braunite, polianite, and manganite. With these oxides are included the silicate, rhodonite, and the carbonate, rhodochrosite, which are sometimes utilized industrially.

Recent advances in the methods of the manufacture of steel have brought into use a number of minerals which until within a few years were of scientific interest only. A special effort was made, particularly during the Great War, to bring together the full series of these ores here displayed. With the cooperation of Mr. Frank L. Hess, of the United States Geological Survey, this was eminently successful. The series includes the ores of tungsten—wolframite, ferberite, tungstite and scheelite; ores of vanadium—hewettite, patronite, and vanadinite; ores of titanium—menaccanite (ilmenite), brookite, and rutile; ores of uranium—uraninite and pitch-blende and molybdenite, an ore of molybdenum. Particularly striking is the large mass of scheelite, weighing 2,500 pounds, from the Atolia mines of California, and the ferberite from Boulder County, Colo., weighing 1,500 pounds. Among the vanadium ores those of Peru are perhaps of the greatest interest and warrant the following transcript from the label. They were secured for the Museum through the cooperation of Mr. D. F. Hewett, likewise of the U. S. Geological Survey.

Vanadium, a rare element allied to phosphorus, is found in unusual concentration in the Department of Junin in central Peru, a region occupied by faulted Juratrias and Cretaceous sediments and injected by a great variety of dikes.

The deposit is a lens-shaped mass occupying a fault, and is composed mainly of (1) quisqueite, (2) patronite, and (3) a cokelike hydrocarbon. In the weathered zone a number of brighter colored, oxidized and hydrated compounds are found, such as hewettite and pascoite. The material was probably forced into the sediments while in plastic and homogeneous condition, and the segregation took place later.

The ores are roasted to drive off the volatile matter and the vanadium is extracted from the residue. The chief value of the element lies in its power to greatly increase the hardness and toughness of steel, when added in quantities up to 1 per cent; but various compounds of vanadium find extensive utilization in the chemical and metallurgical industries.

The titanium ores (rutile) of Virginia, it may be added, are unique and the only ones of their kind worked to-day in America. The material is shown both in the gangue and as concentrates, which are

used largely in the manufacture of carbons for electric lights and for imparting desired tints to porcelain, and to some extent in the manufacture of steel.

Iron ores are displayed in two American cases showing in form of hand specimens all the varieties produced within the limits of the United States. In the wall case extending along the north and east sides of the Range are ores of like nature, but in many cases in larger form, from the principal iron producing localities of the world. Adjacent to this collection is a desk top case against the east window showing the origin of limonite iron ore through the oxidation of iron pyrite and pyrrholite. Another case of similar pattern contains a small collection consisting of weighed samples of various ores each accompanied by the porportional amount of its essential constituents. The collection includes (1) ores of copper in form of chalcopyrite, (2) zinc in form of sphalerite, (3) lead in form of galena, (4) tin in form of cassiterite, and (5) iron in form of magnetite, hematite, and limonite.

The nonmetallic series begins with the American cases on the west side of the hall immediately adjoining the mineral collections. On account of its close relationship with the gem collections, an exhibit of rocks and associated minerals from the diamond mines of South Africa is given first place. This collection was donated to the Museum by Mr. Gardner F. Williams and is described in the catalogue of the Gem collection (Bull. 118, U.S.N.M.).

Under the term asbestos, the commercial world includes several mineral species differing in origin and chemical composition, but alike in possessing a fibrous structure which adapts them to sundry commercial purposes. Of these the mineral chrysotile (amianthus), a fibrous form of the mineral serpentine, is by far the most generally used, both on account of its abundance and the softness and pliability of its fibers which permits of their being woven and used in fireproof fabrics. The smaller samples shown in the American case adjacent to that just described are supplemented by the larger ones from Canada (pl. 19) and Vermont. Of exceptional beauty are the golden yellow varieties from the Grand Canyon region in Arizona. The South African crocidolite and amesite, though closely resembling chrysotile in structure, are of quite difference composition; they are, however, used for similar purposes. The amphibolic asbestos, tremolite and anthophyllite, differ from those described in having a less pliable fiber. They are therefore used mainly in the manufacture of felts and packing materials. They occur mainly associated with the metamorphic schists.

The asbestos exhibit is succeeded by one including the minerals known under the name of talc, or steatite, and pyrophyllite. These

minerals are distinguished by their softness and consequent lack of grit. They differ in that the first named is a hydrosilicate of magnesium while the second is a hydrosilicate of aluminum. They are almost equally soft and used for similar purposes, although perhaps the pyrophyllite is the less common of the two. They are ground and used for talcum powders and lubricants and the massive forms as tailor's chalk, and in the manufacture of gas nipples and electrical goods. The massive impure form, soapstone, is used for laundry and laboratory tanks as well. Succeeding this is a case of micas, under which name is included a number of minerals distinguished by their eminent cleavage which permit of their being split into transparent or translucent more or less elastic foliae. Of all the varieties known, only the white mica muscovite and the pearl-gray phlogopite have at present any commercial value. They are utilized mainly in electrical work, though large quantities are ground and utilized in the manufacture of wall paper and for producing frost effects on Christmas cards, etc.

Cases containing the haloid salts (fluorite, cryolite and common salt), the nitrates, borates and sulphates, including a full series of the Chilean nitrates and the potash salts from the celebrated deposits at Stassfurt, Germany, follow in the order named. Two cases are devoted to the so-called rare earths under which are included the monazite sands and the compounds known under the mineralogical names columbite, samarskite and zirkite—compounds of columbium, cerium, yttrium, tantalum, etc., and the minerals lepidolite and spodumene, which are possible sources of lithia. In continuation of this series along the north wall on the north side of the hall are shown in the order mentioned the minerals sepiolite (meerschaum), magnesite, and dolomite, used in the manufacture of pipes and for refractory materials, or as sources of carbonic acid; limestones, used in quick lime and for fluxes; sulphur and sulphur ores; gypsum, utilized in the manufacture of land plaster, and plaster of Paris; phosphates, utilized for fertilizer purposes; abrasives, including the minerals quartz, corundum, emery, volcanic dusts, diatomaceous earth, etc., as well as the massive materials used in the manufacture of grind and whet stones.

A somewhat striking member of this exhibit is the large mass of diatomaceous earth from Lompoc, Santa Barbara County, Calif. The block is some $4\frac{1}{2}$ by $4\frac{1}{2}$ by $2\frac{1}{2}$ feet in cubical dimensions. The material composing it is about 92 per cent silica, the remainder being mainly water and organic matter, with traces of alumina. The silica portion is composed of approximately 75 per cent of diatoms and 25 per cent of sponge spicules and radiolaria.

Under ochers or mineral paints are included a number of substances, mainly metallic oxides and carbonates in varying de-

grees of purity, which are utilized in their natural conditions, or from which materials for paints can be prepared. These include the iron oxides of prevailing yellow or brown colors, though sometimes red; chromite, used in the manufacture of chrome, yellows and greens; barite or sulphate of barium, used as a substitute for white lead; and a few other minerals utilized to some extent for similar purposes. These are shown in their natural conditions as well as aground, purified, and otherwise prepared for use.

Graphite, plumbago, or black lead as it is sometimes popularly called, is shown in an upright case in all its principal varieties as disseminated in the rock, in clean crystalline lamellar masses like those of Ceylon or in impure and amorphous forms, as those of Sonora, Mexico. A series of jars show the pure Ceylon material as crushed and prepared for use.

The coals, in a similar case, are shown in all phases of carbonization from peat as freshly taken from a bog, through the lignitic or brown coal and bituminous phases to anthracitic and graphitic forms in which metamorphism has progressed so far as to render the material unsuited to fuel purposes.

The kaolins, clays, and fictile material in general occupy two American cases at the west end of the hall. The series are selected to show varieties rather than distribution. They include the kaolins, both crude and washed ready for use in the higher grades of china and porcelain ware, the less pure forms used in pottery and the coarser admixtures utilized for brick tile and terra cotta. While it is recognized that as soon as material passes from the hand of the miner to that of the metallurgist, chemist, or assayer it leaves the domain of applied geology and enters that of technology, it has nevertheless been deemed advisable with many of the nonmetallic minerals, rare earths and metals to include enough of the manufactured product to suggest their possibilities. In the case of some of the metals this has been already referred to (p. 297). Such treatment seems especially desirable in the case of the clays where a possible change in color during firing may be an important matter. Hence in these same cases samples of the raw and baked and partially finished product are exhibited side by side.

On the south side of the hall are shown materials used for structural and monumental purposes, i. e., building stones and marbles. This collection was begun and a considerable part of it was made under the direction of Dr. George W. Hawes while in charge of the geological collections and acting as a special agent of the Tenth Census. The stones are in large part cut into the form of 4-inch cubes for convenience of display and installation. Against the walls and as panels of special bases are large slabs selected to show vena-

tion and other color or structural features desirable in stones used for decorative purposes. The collection comprises upwards of 2,600 specimens and includes representations of all the leading quarries in the United States and those which are important from abroad. (See pl. 20, fig. 1.)

The entire exhibition series, metallic and nonmetallic, of economic minerals, numbers upwards of 9,300 individual specimens.

MINERAL WATERS.

From a strictly scientific standpoint, any water is a mineral water, since water is itself a mineral—an oxide of hydrogen. Common usage has, however, tended toward the restriction of the name to such waters as carry in solution an appreciable quantity of other mineral matter. Of the various salts held in solution, those of sodium, calcium, and iron are the most common. More rarely, or at least in smaller amounts, occur those of potassium, lithium, magnesium, strontium, silicon, etc. The most common of the acids is carbonic, and the next sulphuric.

According to their temperatures, as they flow from springs, the waters are divided into (A) thermal and (B) nonthermal; a thermal water being one, the mean annual temperature of which is 70° F. or more. Each of these groups is again subdivided according to the character of the acids and their salts, as below:

Class I. Alkaline.	
Class II. Alkaline-saline	{ Sulphated.
	{ Muriated.
Class III. Saline-----	{ Sulphated.
	{ Muriated.
	{ Sulphated.
Class IV. Acid-----	{ Muriated.
	{ Siliceous { Sulphated.
	{ Muriated.

The classes may be further subdivided according to the predominating salt in solution, as (1) sodic, (2) lithic, (3) potassic, (4) calcic, (5) magnesian, (6) chalybeate, or (7) aluminous.

Any spring water may be characterized by the presence or absence of gas, when it is designated by one of the following terms: (1) nongaseous, (2) carbonated, (3) sulphureted, (4) azotized, or (5) carbureted.

The water of springs is meteoric and has acquired its mineral matter by gradually percolating downward through the rocks from which it dissolves a certain amount of matter, the quantity and kind being dependent upon the kind of rocks, the temperature and pressure of the water, as well as the gases which it has absorbed.

The collection as displayed in a wall case at the west end of the hall is selected to show kinds and geographic distribution. Inasmuch as this water itself presents to the eye no marks of differentiation the samples are displayed in the original package. The collection is accompanied by a map showing distribution in the United States.

THE GEOLOGY AND MINING INDUSTRY OF LEADVILLE, COLORADO.

A wall case at the north end of the east range on the first floor has been devoted to this collection, of which the following is a transcript of the label:

The prevailing and most important ore of Leadville is an argentiferous galena, which below the zone of oxidation is associated with zinc blende and pyrite. The secondary silver-bearing minerals are argentiferous cerussite, or carbonate of lead; cerargyrite, or chloride of silver; the chlorobromide of silver; less frequently chloriodide of silver; and very rarely native silver. Lead also occurs in secondary forms, as anglesite, or sulphate of lead; pyromorphite or chlorophosphate; occasionally as litharge, and rarely as minium. Zinc occurs in the form of calamine, or silicate, while iron occurs as magnetite, hematite, or limonite, oxidation products of pyrite. Gold occurs in the native state in the form of small leaflets. More rarely occur ores of manganese, arsenic, antimony, molybdenum, copper, bismuth, and vanadium. By far the most important of the ores occur in the blue-gray dolomitic limestone of the Lower Carboniferous formation and associated with intrusive bodies of porphyry, either overlying or cutting across it, and which are known as white, or Leadville porphyry, and gray porphyry. The gangue of the ores is mainly some form of silica (mechanically or chemically combined with hydrous oxides of iron and manganese) and a great variety of hydrous silicates of alumina and barite. The main mass of argentiferous galena or lead ore is found in calcomagnesian beds. The ores containing gold and copper are more frequently found in siliceous beds, in porphyries, or in crystalline rocks.

The ores are assumed to have been deposited from aqueous solution and originally in the form of sulphides. They are of later origin than the inclosing rock, and were deposited not later than the Cretaceous period. It is believed that the metallic contents of the ores were derived mainly from the neighboring and overlying eruptive rocks.

The exhibition comprises all the principal types of rocks and ores, together with a relief map of sections of the region, as collected and produced by the U. S. Geological Survey.

CENSUS OF THE COLLECTIONS, DEPARTMENT OF GEOLOGY.

The exact number of individual specimens in the department can not be given as may readily be understood on a moment's consideration. A rock fragment to-day considered one specimen may to-morrow be broken into a dozen pieces, and a single handful of small fossils may comprise a hundred or thousand individuals. In the exhibition series it is the custom to consider as one specimen the material covered by a single label, though it may weigh from a grain to a ton or more, whether it be a single fossil of pinhead size, or an aggregate

of several thousand. These facts have been taken into consideration and allowances made accordingly in the following table. Owing to the large number of individual specimens considered essential to the proper representation of a single species, the collection of invertebrate fossils is alone numerically as large as all the others of the department combined. As already stated the collections are separated into two series, one placed on public view—the exhibition series—and one stored away in drawers and available only to students and specialists, and known as the study series.

EXHIBITION SERIES.

Physical and chemical geology-----	2, 160	
Mineralogy-----	5, 132	
Petrology-----	1, 704	
Meteorites-----	4 620	
Gems and precious stones-----	4, 000	
Economic geology-----	9, 317	
Invertebrate paleontology-----	24, 000	
Vertebrate paleontology-----	650	
Paleobotany-----	5, 600	
Total of exhibition series-----		53, 183

STUDY SERIES.

Geology, physical and chemical, and economic-----	78, 862	
Meteorites-----	4 550	
Mineralogy-----	35, 931	
Petrology-----	56, 495	
Invertebrate paleontology-----	1, 126, 989	
Vertebrate paleontology-----	19, 350	
Paleobotany-----	36, 215	
Total of study series-----		1, 354, 392
Total number of specimens-----		1, 407, 575

* These figures represent the number of individual specimens and fragments. The total number of individual falls and finds represented is approximately 500.

SOME OBSERVATIONS ON THE NATURAL HISTORY OF COSTA RICA.

By ROBERT RIDGWAY.

[With 5 plates.]

One beautiful morning in May, 1867, after a voyage across the placid Caribbean Sea, beneath a sky equally blue and serene, the passengers on board the Pacific Mail side-wheel steamer *Henry Chauncy* came out on deck to view the scene on shore. We had docked at the port of Aspinwall (now Colón), the Caribbean terminus of the Panama Railway. Many of the group had never before seen the glorious vegetation of the Tropics, and to them the view was startling in its novelty and beauty. To the writer, the effect was such that it had ever since been his desire to see again, but under conditions favorable to a more intimate acquaintance, the virgin forest of the so-called Torrid Zone.

The opportunity so much desired and so eagerly anticipated did not occur until nearly two score years later, when, on the morning of December 8, 1904, after another voyage across the calm expanse of the Caribbean, the densely wooded mountains of Costa Rica loomed high among the clouds, a majestic background to the varied scene. Our steamer had arrived during the night at Puerto Limón, the Caribbean seaport of Costa Rica; a neat little city, whence are shipped to northern markets the coffee and bananas which are the chief exports of the little Republic. Far beyond the town, but seemingly only a few miles distant, the scarred and calcined summit of the Volcan de Turrialba constituted a conspicuous landmark, every detail sharp and distinct through the transparent atmosphere. On either hand stretched the coast line; to the right, snowy breakers dashing over coral reefs, the exquisitely wooded little island of La Uvita, just offshore, resting like an emerald on the sapphire waters of the bay; to the left a wall of giant grasses, except where the tall plumes of coconut palms fringed the higher portions of the shore line.

The train for San José, the capital, nestling two-thirds of a mile above the sea among the mountains of the interior, leaves for its des-

mination in the morning. At first the railway skirts the coast, the blue expanse of the Caribbean close by on the right; on the left a solid wall of primeval forest, except where this is broken by an occasional small clearing. Soon the track turns inland, alternately passing through swampy forests of palms and other tropical vegetation of bewildering splendor, and, on ground less wet, extensive plantations of bananas, where are produced most of that fruit which is consumed in the United States. Ere long the ground, still densely wooded, becomes less flat; the verge of the coastal plain has been reached, and the train meanders among the foothills, which become higher and higher until the engine puffs strenuously in its effort to overcome the increasing grade. The aspect of the forest gradually changes; palms are less in evidence, a solid mantle of closely matted "broad-leaved" trees, in appearance essentially like those of our northern woods but with foliage of a darker, more somber green and with broader and more dome-shaped or flattened crowns, forming the mass of the all-embracing forest. The air becomes sensibly cooler until, toward the summit of the line, the temperature is as bracing as that of a fine October day in the States. The scenery from the car windows is constantly changing, for every turn of the road—and the curves are very frequent—brings into view a picture more magnificent, if possible, than those left behind. Far below, on the left, through a deep and densely wooded gorge, rushes the Rio Reventazón, the mountain wall beyond backed by range over range of mountains until the most distant blend with the blue of the sky.

In proceeding upward the first considerable break in the continuity of forest is where the Indian village of Tucurríqui is seen across the canyon of the Reventazón, perched high above the foaming stream on a comparatively level bench, surrounded by extensive areas of open pasture and cultivated fields of sugar cane, maize, and upland rice. Gradually such open spaces become more frequent and of greater extent until near Cartago, the former capital, on the southern slope of the Volcan de Irazú, little woodland can be seen. Here, 4,500 feet above the sea, the bracing, almost chilly, air and stone fences around the fields are strongly suggestive of New England; a very transient illusion, however, for many of the telegraph and telephone poles are observed to bear not only foliage of their own but also orchids, ferns and other epiphytic plants; the night-blooming cereus and other cacti grow upon the stone walls, and the low red-tiled houses of the inhabitants are of a style of architecture never seen in northern countries. The highest point along the railway is reached at El Alto, a few miles beyond Cartago, at an elevation of exactly 1 mile above sea level. Thence the road descends to San José, the capital, near the head of a broad valley between the Cordillera Central, just crossed, and the Cerro de la Candelária,

at an elevation of 3,500 feet. From San José are plainly visible the volcanoes of Irazú, Barba, and Poás, of the central range; in the opposite direction the Candelaria Mountains are seen so clearly that the fields of sugar cane, maize, and rice which cover their slopes can easily be recognized by the hue of green peculiar to each, while close to the summit of the highest peak the gigantic evergreen oaks are clearly silhouetted against the sky.

From San José to the Pacific Ocean extends a region greatly different in appearance and climate from that of the eastern or Caribbean slope. The latter is a region of perennial rains; indeed, the rainfall is excessive during a considerable portion of the year, and even during the drier months there are daily showers, mostly "sun showers" of short duration, though often several occur each day, the higher portions of the mountains being perpetually saturated with rain or dense, wet fogs.¹ On the Pacific slope, however, the year is sharply divided into two very different seasons, a wet and a dry, each of six months duration. The inhabitants speak of the former as their winter (*el invierno*), the latter as their summer (*el verano*). The dry season is practically rainless and cloudless: many trees shed their foliage as completely as do those of northern countries in winter;² pastures become poor, and toward the end of the season conditions of severe drought often prevail. On the other hand, the forests, pastures, and plantations of the Caribbean slope are perpetually green; the trees shed their leaves, to be sure, but, except relatively very few species, they are dropped one by one or a few at a time and are at once replaced by new ones.

Two visits were made to Costa Rica, one covering about six and the other three months, during which the country was traversed from ocean to ocean and from sea level to the summit of several of the highest mountains. A study of the bird life was the main purpose of the explorations, and a large and valuable collection was made for the United States National Museum. In this work every possible assistance was rendered by the Government of Costa Rica, which generously detailed the taxidermist of the Museo Nacional to accompany the writer during his different excursions, besides extending other courtesies; and also by my friends Señor Don José C. Zeledón, and Señor Don Anastasio Alfaro, director of the Museo

¹ The average annual rainfall of the Caribbean slope is said to be from 220 to 200 inches, and at one station, Sarapiquí, on the northern slope, 112 inches were recorded during the month of December alone, while at Puerto Limón there was a rainfall of 41 inches in three days.

² In some parts of the Pacific slope, as, for example, in the forests of the Rio Grande de Tárcoles, I estimated that between one-third and one-half of the trees were leafless.

Nacional, one or the other of whom, sometimes both, accompanied me on every trip. It was through the help of these two gentlemen, both excellent ornithologists and unexcelled as companions in the field, that it was possible to make collecting trips to points that would otherwise have been inaccessible to me. Headquarters during our stay in Costa Rica were a commodious and perfectly appointed house, with all modern conveniences, the home of old friends, in the outskirts of the capital, at the edge of a beautiful parklike expanse called La Sabana (The Savanna), connected with the city by trolley. Set in ample grounds which were decorated by the choicest flowering trees and shrubs of the tropics and such roses as are never seen in a less genial climate—teas and hybrid-teas of every variety, from which large basketfulls of exquisite flowers could be gathered the year around—tropical fruits of all sorts, and, what seemed most strange, a kitchen garden wherein grew, to perfection, most of our northern vegetables almost alongside of pineapples, oranges, lemons, grapefruit, bananas, grenadillas, sapotes, aguacates, papayas, and other purely tropical fruits—altogether an ideal home, but one reflecting the cultivated taste of our generous host and charming hostess.

From La Sabana excursions were made in many directions; to the volcanoes which form the culminating points of the central cordillera; to the Pacific coast at Pigres, where the Gulf of Nicoya merges with the ocean; to Santo Domingo de San Mateo, then the terminus of the Ferrocarril al Pacifico, since extended to the coast at Punta Arenas; to near the base of Turubales, southeast of Santo Domingo; to Escasú, at the northern base of the Cerro de la Candelária, and Monte Redondo, a coffee estate on the opposite side of that range; and on the Atlantic or Caribbean side, to the haciendas Bonilla, Guayabo, and Coliblanco on the southeastern side of the volcano of Turrialba; to El Paraiso, at the base of the cinder-cone of Turrialba, and San Juan on the southern slope of Irazú, above Cartago.

These excursions, together with many minor trips, afforded ample opportunity for studying the natural history of the country at close range. All trips not made by rail were, necessarily, made on horseback, the use of wheeled vehicles being confined to the few cart roads connecting the various centers of population. One trip (the second one from Santo Domingo to Pigres and return, a distance of about 18 miles each way) was made on foot.

It would be impossible to describe in a limited space everything seen that is worthy of description; to do so would require a full volume. For obvious reasons, therefore, the following observations will

be mostly confined to such subjects as most interest a naturalist—the climate, the appearance and composition of the forests, and the animal life, especially the birds, since these were the special objects of study. The temptation is strong, however, to digress to the extent of remarking that perhaps the most striking result of our experience was the conviction that many of our preconceived notions concerning the Tropics are pure myths, and that the nomenclature of the earth's climatic zones, as taught in our school geographies, is sadly in need of revision. For example, it would far better express the truth were the so-called Temperate Zone changed to Intemperate Zone, and the former name transferred to the so-called Torrid Zone. Certainly at no time and at no place was the heat of midday more oppressive than it often is in July or August in the States, and the nights, even in the *tierra caliente* of either coast, were invariably cool and pleasant; while at higher altitudes, even in San José, the nights were uncomfortably cool, since even the best houses are not provided with means for artificial heating.³ Pedestrian trips even in the *tierra caliente*, though often requiring unusual exertion on account of difficult ground or from having to cut one's way through dense undergrowth, involved no more discomfort than a midday ramble in midsummer at home.

According to the popular notion, for which our textbooks are largely responsible, the Tropics abound with reptiles, especially poisonous snakes and boa constrictors. The fact is, that snakes of any kind are no more often seen than in the United States. We saw just three during six months, two of these being non-venomous kinds.⁴

Neither are tropical birds songless nor tropical flowers without odor, as we have been taught; on the contrary, it is exceedingly doubtful whether in any part of the temperate zone (so-called) there are any birds with notes so thrilling as those of certain species found in tropical countries; and it is, or ought to be, well known that the fragrance of many tropical flowers is almost overpowering. Nor is

³At the Government experimental farm at Santo Domingo de San Mateo, on the Pacific coastal plain (the hottest part of the country), the director informed me that the highest record for the station was 96°. The maximum temperature, however, is near 90° every day in the year, but the nights were invariably so cool that blankets were required. At Colihlanco, about 6,500 feet above sea level, it was necessary to go to bed under heavy blankets not later than 7 p. m. in order to keep warm.

⁴"There is a general impression among Europeans that tropical forests teem with venomous snakes. Although I have spent the greater part of the last 10 years in the forests of Venezuela and Colombia, I am ashamed to confess that I am not the hero of any thrilling snake adventure. As a matter of fact, I never give snakes a thought, and I will crawl through brushwood on hands and knees in search of any bird I may have killed with as little concern as if I were in my own garden. But I respect wasps, hornets, and ants." (Eugene André, *A Naturalist in the Guianas*, p. 160.)

During three month's residence in the Valley of Quito, Ecuador, Professor Orton saw but one snake. (*The Andes and the Amazon*, p. 107.)

it true that a greater proportion of the birds are more brightly colored in tropical than in temperate regions.⁵

It is also a very general, but nevertheless wholly erroneous, popular notion that flowers are far more plentiful in tropical than in temperate climates. This may be true to the extent that the number of kinds is much greater; but even this superiority is very much a question of locality and season. In the dense forests of the humid Caribbean slope of Central America flowers are, as a rule, very little in evidence. There are, however, innumerable species, some of them very beautiful; but they are scattered and rarely if ever form a conspicuous feature in the landscape, except when certain trees are in bloom. In descending from Cartago to Puerto Limón, in May, a very large tree was in flower, forming here and there on the mountain sides solid masses of brilliant yellow which fairly gleamed by contrast with the somber dark green of the surrounding forest; and in the valley of San José a much smaller tree, having leaves like the catalpa and evidently belonging to the same natural order, also bore bright yellow flowers, and another bignoniaceous tree, which in the forests near the Pacific coast attained a considerable size, displayed large catalpa-like flowers of peach-blossom pink. These, together with a tree morning-glory bearing white flowers, seen at Monte Redondo, were the only conspicuous masses of bloom observed in Costa Rica. Had we been able to remain on the Pacific slope until after the commencement of the rainy season, however, it is probable that our experience would have been different, for then, with a general revival of vegetation, that part of the country is said to become exceedingly floriferous.⁶ Many species of orchids, passion flowers, bignoniaceous climbers, and various other kinds of plants produce flowers of brilliant or beautiful colors, but they are so scattered through the forest

⁵ In North America north of Mexico there are about 366 species of land birds, of which 96, or about 26 per cent, may be called brightly colored. In Costa Rica, with approximately 556 species, 161, or about 27 per cent, may, by the same standard, be called brightly colored. It is quite true that among tropical birds there is in the aggregate a larger number of brightly colored birds, but so there is of dull-colored species also; in fact, there are in tropical America entire families of birds, some of them including 100 or more species, of which practically all are as dull colored as it is possible for a bird to be. It is in the vastly greater *variety* of bird life that the Tropics excel. In Costa Rica, for example, with an area barely greater than half that of the State of Indiana, there are about 130 more species of land birds than are found in the whole of North America north of Mexico, including Greenland and Alaska. The same great diversity obtains in most other forms of life, especially in the vegetable kingdom, in which the disparity between temperate and tropical regions is incomparably greater, because in both the number of plant species is everywhere many times that in any of the animal kingdoms.

⁶ Referring to the Pacific slope of Nicaragua, the climate and natural productions of which are essentially identical, Thomas Belt (*The Naturalist in Nicaragua*, p. 41) says: "The barrenness of the landscape is relieved in March by several kinds of trees bursting into flower when they have shed their leaves, and presenting great domes of brilliant color—some pink, others red, blue, yellow, or white, like single-colored bouquets. One looked like a gigantic rhododendron, with bunches of large pink flowers."

or so hidden among the foliage that they only now and then attract attention; and we never saw anywhere in Costa Rica an extensive display of bright colors at all comparable to the splendid mass-effect of mountain laurel, rhododendrons, and azalcas on our more southern Appalachian mountains, or the vast expanses of golden yellow compositæ that, in late summer and early fall, glorify the open country of our Middle West. Unquestionably the variety in tropical flowers is far greater, and many are certainly more beautiful or showy than any of ours; but usually one must search for them or come on them by accident. In the cloud zone, from about 6,500 to over 9,000 feet above sea level, there are many kinds of flowering trees, shrubs, climbers, and parasitic or epiphytic plants, but their flowers, while often bright colored or beautiful, are rarely conspicuous at a distance.⁷

The one absolutely distinctive feature of the Tropics, especially the more humid portions, is the vegetation. This is so different from that of any portion of the United States that we have nothing comparable—merely a faint suggestion in the “hammocks” of southern Florida. In the Naturalists’ Voyage in the *Beagle*, Darwin remarks:

When quietly walking along the shady pathways [at Bahia, Brazil], and admiring each successive view I wished to find language to express my ideas. Epithet after epithet was found too weak to convey to those who have not visited the intertropical regions the sensation of delight which the mind experiences. I have said that the plants in a hothouse fail to communicate a just idea of the vegetation, yet I must recur to it. The land is one great wild, untidy, luxuriant hothouse, made by nature for herself, but taken possession of by man, who has studded it with gay houses and formal gardens. How great would be the desire of every admirer of nature to behold, if such were possible, the scenery of another planet; yet to every person in Europe it may be truly said that, at the distance of only a few degrees from his native soil, the glories of another world are open to him. In my last walk I stopped again and again to gaze on these beauties, and endeavored to fix in my mind forever an impression which at the time I knew sooner or later must fail. The form of the orange tree, the coconut, the palm, the mango, the tree fern, the banana will remain clear and separate: but the thousand beauties which unite these into one perfect scene must fade away; yet they will leave, like a tale heard in childhood, a picture full of indistinct, but most beautiful figures.

And in his “Retrospect” that distinguished naturalist further says:

When I say that the scenery of parts of Europe is probably superior to anything which we beheld, I except, as a class by itself, that of the intertropical regions. The two classes can not be compared together. As the force of impressions generally depends on preconceived ideas, I may add that mine were taken from the vivid descriptions in the Personal Narrative of Humboldt, which far exceed in merit anything else I have read. Yet with these high-wrought ideas my feelings were far from partaking of a tinge of disappointment on my first and final landings on the shores of Brazil.

⁷ On the volcano of Poás, however, there was a mistletoe which completely covered certain trees with a nearly solid mantle of bright red flowers.

Darwin's impressions of tropical scenery, or rather of tropical vegetation, were probably the same as those of others when, for the first time, they gazed on the splendid vegetation of the humid Tropics; that is, those parts where abundant and frequent rains produce a perennial verdure, for the contrast in the vegetation of the humid with that of the arid Tropics is even greater than between the former and that of the more humid parts of the Temperate Zone.

The dominant feature of the humid Tropics is the forest. This covers the whole country, except where cleared by man, with a continuous heavy mantle, only the extreme summits of the higher mountains being treeless; and in Costa Rica the "timber-line" is not the effect of altitude but of eruptions of hot ashes, cinders, or gases from the volcanic vents. Although continuous in extent, the forest presents great differences in its appearance and composition according to altitude, the amount and continuity of rainfall, slope exposure, and character of soil. According to these variations the forest may be roughly divided into the following main types:

I. The perennially evergreen forests of the Atlantic or Caribbean slope, with the following subdivisions: (a) The forests of the coastal plain; (b) the forests of the foothills and lower mountain slopes; (c) the forests of the cloud zone.

II. The only partly evergreen forest of the semiarid Pacific slope.

Of whatever type, however, all present one feature in common, though in varying degree, namely, extreme exuberance of growth and variety of composition.

The Atlantic or Caribbean coastal-plain forest I am least familiar with, having seen it only in passing through by train, except that portion which, in a more or less modified form, overlaps or merges into the mountain forest among the foothills; consequently, the following observations apply to the other subdivisions only. It may be remarked, however, that the coastal-plain forest represents the acme of luxuriance in tropical vegetation, maximum development in size of the trees, and of variety of palms and succulent plants with large and conspicuous foliage.

The forests which cover the foothills and greater part of the slopes of the mountains are, in general appearance, more monotonous and somber than those of the coastal plain. Seen from the outside or at a little distance, this forest does not seem very different in appearance from our northern primitive hardwood forests. The general color is perhaps a darker or less vivid green and there is something in the contour of the tree tops which seems unfamiliar to the observer from the North; they are relatively broader, flatter and more compact, and when a bare stem can be seen it seems disproportionately slender for the broad crown which it supports. For much the

greater part of its extent, palms are very little in evidence; often none at all can be seen in an extensive expanse of tree tops. Once inside, however, and where the trunks of the trees are exposed by clearings, the difference is so great that even the most luxuriant broad-leaved forests of the more southern United States convey but a faint suggestion of their bewildering exuberance and infinite variety in details of their composition.

The average tropical forest is practically impenetrable, often absolutely so without free use of the wood knife or machete. The trees, as a rule, are no closer together, and the biggest rarely larger than in the heaviest of our virgin hardwood forests. The occasional "giants" excel ours mainly in the great development of buttresses at the base, and wider expanse of their crowns; and I have never seen in tropical forests single tree trunks surpassing in uniform thickness, length, or symmetry some of the gigantic sycamores, tulip trees, black walnuts, pecans, burr oaks, and bottom red oaks which formerly grew in the rich alluvial bottom lands of our Middle West. But in tropical forests there are no open spaces or vistas; almost everywhere between the larger trees is a tangled maze of lesser vegetation through which a path must be cut as one proceeds. It is this minor growth that displays almost endless variety in form, size and color of foliage, for the leaves of the trees themselves are singularly uniform in type. Cablelike vines are stretched from tree to tree and hang in loops or spirals, some of them zigzag and curiously flattened; aerial roots of epiphytic plants growing on the larger branches of the trees are suspended from tree tops, hanging straight down like cords or ropes, frayed or fringed at the lower end by incipient rootlets, or, having reached the ground, have taken root there and will soon form separate tree trunks, or have already done so; climbing plants of numberless kinds ascend these cablelike growths, and a network of climbing ferns and other tough-stemmed climbing plants interlace the whole. Each tree is itself a veritable botanical garden, for not only are the lofty crowns burdened with masses of parasitic or epiphytic plants—ferns, orchids, bromeliads, aroids, cacti, and others belonging to unfamiliar orders—but the trunks themselves are similarly decorated. Often what seems at first sight to be a single trunk will on closer view prove to be a compound one, the original stem lost in a confusion of several twisted woody climbers, the foliage of each forming a separate mass or tier. The ground itself is covered with plants of numerous kinds, lycopodiums, peperomias, ferns, etc., the kinds varying greatly with locality. None of our northern forests contain anything like so great a variety in the trees themselves; rarely are two examples of the same species seen near together, but usually each tree is different from all others in its vicinity.

So exuberant is the growth of vegetation in the humid tropics that all spots from which the surface soil has been removed are quickly covered with a new growth. Even steep railway cuts are densely clothed with ferns, lycopodiums, begonias, and numerous other plants, and a bare spot is to be seen only where there has been a very recent landslide or where an overhanging bank has fallen. The fences inclosing fields and plantations are living fences, made by merely setting freshly cut poles or stakes into the ground; even the telephone and telegraph poles often break out in foliage, and trees cut down inside a coffee plantation and taken outside had, as they lay on the ground, taken root and thrown out new branches.

As in parts of the Temperate Zone, there are in the Tropics many local variations in the character of the forest. Some of these departures from the prevalent type are difficult to account for. Occasionally one finds an area of forest on which the growth is conspicuously different from that of adjoining tracts. One such, on the hills immediately above Bonilla^{*} was as different in its appearance and composition from other forests in that neighborhood as are the post-oak and blackjack woods from the luxuriant mixed growth of rich bottom lands in the middle or southern portions of the eastern United States. There was little exuberance in either the undergrowth or the epiphytic and parasitic decorations upon the trees, and but for the obvious fact that all the plants were different one might easily imagine himself in an ordinary hardwood forest in the States.

On the Pacific slope, the country lying between the Central Cordillera on the north and the Candelária Mountains on the opposite side of the San José Valley, as well as the mountains themselves up to the cloud zone, and thence to the coast, has been completely deforested, for it is there that the bulk of the population lives. Consequently it is only on the higher parts of the mountains and in certain places near the coast that any considerable part of the original forest remains. Two trips, one on foot, the other on horseback, were made through the virgin forest of the Pacific coastal plain occupying the district about the lower course of the Rio Grande de Tárcoles, near the Gulf of Nicoya, through which a cart road to Pígres had been cut. There, two conspicuous features at once attract attention; the rank undergrowth of canna-like plants (whether really cannas or heliconias, I am unable to say), growing 10 to 12 feet high, which covers the greater part of the ground, much as canebrakes do in portions of our southern forests (pl. 5, fig. 2), intermingled with clumps of small and beautiful but frightfully thorny palms, while most of the large tree trunks were decorated for their entire length by a climb-

^{*} The hacienda of Bonilla is on the Caribbean slope at an altitude of 2,600 feet.

ing aroid, the *Monstera deliciosa*, with immense caladium-like but divided leaves, and bearing an edible fruit. Most of the trees were unknown to me by name, but among them were many gigantic fig trees with grotesquely compound stems (grown from the slender aerial roots which originally descended from the top of some tree on which the fig grew as an epiphyte, the parent tree itself long since strangled and decayed).⁹ It being the dry season, a large proportion of the trees were quite leafless. Here, and here only, was seen the magnificent leguminous tree called by the natives *guanacaste*, its lofty crown of small pinnate foliage (much like that of the honey locust), supported on a tall, straight trunk covered with a smooth gray bark, much like that of the beech. This was probably the tallest tree in the forest, but to say how tall it grew would be mere guesswork; I only know that a pair of macaws who were squabbling among the lower branches of one, in plain view, looked no larger than doves, and that a full charge from a shotgun merely sent them away, the forest resounding with their discordant squawking as they disappeared. A tree of unknown species standing some distance off the road attracted attention from the enormous spread of its massive crown, which could have been scarcely less than 200 feet across. Curious to know the size of its trunk we cut a swath through the undergrowth of cannas to its base. The buttresses connecting it with the ground were so high that the tape could not be passed around the trunk, but the distance, on the ground, between the extremities of opposite buttresses was 30 feet.

While the forests of the lowlands are in some respects more beautiful and certainly more varied, I believe that the maximum of density, especially of the undergrowth, is attained by those of the higher altitudes, or in the so-called cloud zone. These vary in character not only with altitude and slope exposure but also on different mountains; but, being constantly saturated with moisture from daily rains or heavy fogs all are perpetually dripping and perennially green; and it is here that ferns (including tree ferns), mistletoes, bamboos, mosses, and lichens are most abundant. Further detail concerning these rain forests will be reserved for descriptions of special localities we were so fortunate as to visit.

Notwithstanding the splendor of their development in the way of luxuriant and infinitely varied undergrowth and decorative epiphytes, parasitic plants, and vine drapery, the foliage of the trees themselves in a tropical forest is singularly uniform in character. Of course the palms are excepted, as are also the beautiful tree ferns, which in a variety of species, now and then form a conspicuous feature in

⁹ We measured one of these fig trees that was 30 feet in diameter, including the spaces between the several stems. This particular tree included among its epiphytic decorations a fine specimen of the leaf-cactus (*Phyllocactus*). (See pl. 1, fig. 2.)

the cooler forests of the cloud zone; but the greater number of the dicotyledonous trees, which almost everywhere predominate, have leaves of practically one form—oval, ovoid, oblong, or elliptical, with entire margins, but varying, of course, in size, venation, and other details. I searched everywhere in vain for a leaf of tree, shrub, or climber with serrated margins. No leaves at all like those of our oaks (excepting those of the laurel-oak group), maples, sycamore, sweet gum, or others of our northern woods with deeply divided or lobed leaves were seen, the nearest approach being the *guarumo* (a species of *Cecropia*), conspicuous for its large, palmately-divided peltate leaves. There are a few trees with heart-shaped leaves, like those of our redbud and catalpas, and a considerable number with pinnate leaves, especially of the sort with small leaflets and fernlike foliage, like our locusts (*Robinia* and *Gleditsia*), and, indeed, belonging to the same natural order of plants. The latter are particularly numerous on the Pacific side, while on the Atlantic slope, the so-called Spanish cedar, or *cedro*, has more coarsely pinnate leaves, resembling those of the black walnut or *Ailanthus*; in fact, the big cedros much resemble in appearance (except for their enormous buttresses) gigantic black walnuts. As before remarked, the prevailing oval, ovoid, oblong, or elliptical leaves borne by the majority of the trees, vary greatly in size and other details. Many trees on the Caribbean slope had leaves more or less resembling those of our southern evergreen Magnolia (*M. grandiflora*); and I remember one in particular (at Guayabo) whose leaves were so hard and heavy that in falling (as they did at intervals during our presence there in May) they made a noise when they struck the ground like that of shingles dropped from a housetop.

Tree trunks with rough or deeply furrowed bark, like that of our black oaks, are rare in tropical forests, and it is only occasionally that one is seen with a roughish or moderately furrowed bark, like that of our white oaks, tulip tree, sweet gum, etc.; the prevailing style is a smoothish gray one, more or less like that of the beech, though there are many with smooth bark of some other color, as the *hurá*, with a smooth pinkish buff stem (pl. 5, fig. 1), another, whose name I did not learn, with bark of almost snowy whiteness, and one with bark of trunk and branches a bright venetian red. Others have cream-colored, buff, or greenish smooth bark, while many are conspicuously mottled.

With all the endless variety and magnificence of detail within a tropical forest, this is hidden from view except where inroads have been made by the hand of man. There are no vistas such as often occur in our northern woods, except where the solid mass of vegeta-

tion is broken by some stream or where clearings have been made; all is a matted and tangled mass of vegetation through which it is necessary to cut one's way. On the Pacific slope, where demolition of the forest has been sadly overdone, the long dry season greatly facilitates the burning of the trees and undergrowth, and in consequence, as has already been stated, there is no real forest between San José and Punta Arenas. On the Atlantic slope, however, the labor of clearing is far greater and therefore, except on the coastal plain, where extensive areas have been cleared for banana plantations, most of the openings in the virgin forest are the partially cleared *potreros* (woods pastures) of the several large cattle haciendas. Very little of beauty has been left in the more densely inhabited portions of the Pacific slope, so nearly complete has been deforestation there; but in the *potreros* of the Atlantic slope, where only the smaller trees and undergrowth have been removed, and the ground sown to tropical pasture grasses, as at Bonilla, Guayabo, Coliblanco, and El Paraíso, one can walk freely beneath the large trees that have been spared and realize more than elsewhere the charm of tropical vegetation. These are, indeed, the real "beauty spots," and it was the writer's good fortune to remain at each of the places named for from several days to several weeks. To adequately describe all that was seen there would be impossible; but mention of the more striking features of these wonderful spots may be worth the reader's time.

Our first visit to the "cloud zone" was to the summit of the volcano of Poás (8,700 feet)—the only constantly active volcano of Costa Rica—which was reached by rail from San José to Alajuela, thence to the base of the cinder-cone by horseback. The most noteworthy incident of the railway trip was the astonishing sight of children coasting—actually coasting in the Tropics. It was the middle of the dry season, and the long drought had dried the grass on the steep hillsides to such a degree that walking upgrade with shod feet was well-nigh impossible. The barefooted children, however, were making the most of these slippery hillsides, and, with improvised sleds, of different patterns, were gleefully sliding downhill, "belly-buster" and otherwise, and having every whit as much fun as our youngsters do in coasting down a snow-covered slope.

Leaving Alajuela at dusk, we arrived during the night at San Pedro de Poás, where a halt was made for supper. Resuming our journey, a brilliant moon illumined the way, the moonlight gradually merging into daylight as the sun rose above the cordillera. The *lechería* (dairy farm) at the upper edge of the deforested zone was reached in time for breakfast, after which our horses plunged, single file, for the trail was wide enough only at intervals for two animals

to pass, into the dense and luxuriant forest. The trail was everywhere knee-deep in black mud, often deeper, for the ground here never becomes dry; and the mud being filled with roots of the trees, our horses constantly stumbled. Except for the novelty of the surroundings, it can not be said that this portion of the trip was particularly enjoyable. Here in this wonderful forest we first saw the *quetzál*—the royal bird of the Aztecs, perhaps the most gracefully beautiful of all birds—in a setting no less magnificent than itself; for it is in the cloud-zone forests that vegetation reaches its maximum density, and its decorative features, while very different from those of the *tierra caliente*, are no less beautiful and varied.

We emerged from the forest tunnel upon an open space of circular form, evidently an ancient crater¹⁰; here our horses were tethered, for we were near the base of the cinder-cone. Walking through a narrow belt of more open forest, we entered the last zone of vegetation, a dense and tangled chaparral, beyond which rose the steeper but more uniform slope of scoriaceous material ejected from the crater during past eruptions. On reaching the summit we were disappointed to find the crater completely filled with dense clouds; but a strong wind soon dispelled these and revealed a vast pitlike amphitheater with nearly vertical walls, said to be 400 meters (about 1,300 feet) high, enclosing a nearly circular pit, apparently a mile or more across,¹¹ with a boiling lake occupying a portion of the crater floor. The walls everywhere bore evidence of plutonic action, in places being red, as if calcined. Soon the clouds drifting in from the Caribbean Sea again closed the crater, and we descended, by a different trail, to the shore of a beautiful lake of nearly ice-cold water—another extinct crater—hemmed in on all sides by dense forest. At intervals during our stay the stillness was broken by explosions of the boiling lake within the crater, sometimes of such force that the ground trembled, and the noise of the explosion was like that of heavy artillery.¹²

Coliblanco is near the foot of the southern slope of the volcano of Turrialba, at an elevation estimated to be about 6,500 feet. The estate is literally hewn and burnt out of the primitive forest, which commences almost at the back door—more exactly at the base of the steep mountain slope a half mile or so in the rear of the house—the intervening space having been cleared of the smaller trees and undergrowth, and the grown sown to pasture grasses. The photograph (pl. 3, fig. 2) will give some idea of the general appearance

¹⁰ The upper edge of this open space is shown in plate 2, figure 1.

¹¹ The distance may in reality be less, but I did not get information as to this.

¹² The year following our last visit there was a great eruption of this volcano, during which the pillar of steam or smoke ascending from the crater was estimated to be some 7 miles high.

of the *potrero* but can convey no conception of the striking and harmonious color-scheme, in which, no less than in variety of its composition, consists the glory of tropical vegetation. Almost every tree here has its own peculiar hue of green; a deep dark, almost olive, green predominates, but some trees are blue-green, some yellow-green, some nearly golden, others almost russet, according to the species. Most of the trees support flowering vines, epiphytes or parasites (orchids, bromeliads, aroids, mistletoes, etc.), while some bear showy flowers of their own; one tree especially, an *Erythrina*, with bright scarlet flowers, was much frequented by humming birds. In some places, mostly on the moister slopes or on the sides of ravines, grow clumps or groves of beautiful tree ferns, of half a dozen or more species, some of them 30 to 40 feet high. I very much regret that my attempts at photographing these were failures, on account of underexposure. In very wet or marshy tracts are large caladiumlike aroids whose immense leaves more than once served as a shelter from hard showers; one had only to sever the stem with a machete and use the leaf as umbrella. Nowhere else have I ever seen so great a variety of ferns. These were mostly epiphytic, growing on trunks and branches of trees, on stumps and old logs, as well as on the ground. During one of my tramps I happened on a stump which was completely covered with growing plants, ferns predominating. These exhibited such variety that it occurred to me to see how many kinds of ferns there were; when I could find no more that were different, I counted 21 species!

The hacienda of El Paraiso is about 3,000 feet above Coliblanco (9,680 feet above sea level), near timber line on Turrialba. The name, meaning "The Paradise," is well chosen, for it seemed that the very climax of beauty was there attained. The air was cool and bracing, though at night much too cold for comfort. At times each day clouds from over the Caribbean Sea drifted in and enveloped everything in a wet, impenetrable fog, so dense that one could not see the nearest objects, and therefore had to remain stock-still until the cloud had passed. The intervals of bright sunshine were frequent, however, and of longer duration; and it was then that the prospect was surpassingly lovely. Several hundred acres had been completely cleared of all undergrowth and many of the trees as well, and the ground sown with European pasture grasses, producing the effect of a large, well-kept park, with long vistas through clumps and groves of wonderfully beautiful trees, over lawns of vivid green, cropped close by grazing cattle and studded with buttercups, daisies, sweet violets, and other European flowers, sprung from seed mixed with that of the imported grasses. But there never was a northern park with such trees—so beautiful in form or foliage, or

so bedecked with flowers. Almost every tree bore flowers, either its own or of some climbing, epiphytic or parasitic plant, while all were further embellished by brightly colored (in part crimson or scarlet) rosettelike tufts of "air plants" (bromeliads), or fronds of ferns of many kinds. To the right, as one ascended the gentle slope, rose, nearly 1,500 feet higher, the steep cinder-cone of the volcano, seemingly so near that every detail could be distinctly seen (pl. 4, fig. 2). To the left, overlooking a broad expanse of primeval forest, rose the long ridgelike mass of Irazú, the one mountain of Costa Rica that is higher than Turrialba. The deep ravines on either side of the gently sloping shoulder on which the hacienda rests were still occupied by an impenetrable primeval growth. Here severe cold is felt at night, especially during the months that correspond to our winter, when ice frequently forms, on one occasion to the extent that the water pipes supplying the house burst. These pipes were, however, laid above the ground. Even during our two visits, in March, the nights were uncomfortably cold, and early in the morning the pastures were white with frost.¹³ Still, the vegetation here was composed, at least in a large part, of tropical or subtropical types; there were bamboos, at least one species of arborescent palm, tree ferns, and many kinds of epiphytic bromeliads. The majority of the trees belonged to genera or even orders unknown to me, not a single genus of the North Temperate Zone being recognized. With so low a temperature (which varies but little throughout the year, the fluctuations of the thermometer being most marked within each 24 hours), it seems strange that so varied and beautiful a vegetation, evidently in part at least of tropical affinities, could exist. Possibly the explanation may be found in the absence of any sudden or very great changes in temperature, and the gradual adaptation of the flora to the conditions. It is said that, while ice frequently forms on both Turrialba and Irazú, snow never falls on either. Why this should be so may, perhaps, be explained by some meteorologist.¹⁴

In the beautiful park of El Paraiso birds seemed to be more numerous than in other parts of the country, evidently because they could be more easily seen. Large coal-black robins, with golden beak and eye-ring, ran gracefully upon the greensward, and it was rarely if ever that one was out of hearing of the twitter of humming birds or the whirl of their wings; among the latter being a most brilliantly colored species (the *Panterpe insignis*), remarkable for the fact that the sexes are quite alike in coloring. That finest of all birds, the resplendent trogon or *quetzál* found here a

¹³ Readings of a thermometer, in the shade, on March 27 were as follows: 5 a. m., 38°; 6:30 a. m., 42°; 1 p. m., 61°; 6 p. m., 52°.

¹⁴ A possible explanation is suggested by the circumstance that a minimum temperature and precipitation are rarely, if ever, coincident, the former occurring at night, the latter during the day.

congenial home, and was very tame; for several minutes I watched a pair perched in a tree close by, and could easily have shot them but did not—they were too beautiful and confiding.

The ascent of the cinder-cone of Turrialba, although fatiguing, on account of the steepness of the slope and rough character of the surface, was well worth the exertion. The larger growth about the hacienda almost suddenly gave way to a dense and tangled chaparral, which gradually became more open and composed of smaller bushes, among which were many vacciniums or related ericaceous shrubs—the first plants of unmistakable northern type that were recognized—and scattered herbaceous plants, among the latter a scarlet-flowered *Salvia*, much frequented by a small humming bird (*Selasphorus flammula*); even this scanty growth finally ceased, the whole surface consisting of rocks, scoria and sand. The crater is a comparatively narrow but profoundly deep fissure, only a few hundred yards across but several times that length, with perpendicular walls some 2,000 feet in depth. Crawling to the edge of this chasm and peering cautiously into its depths, no evidence of present activity was visible within; but above the northern wall, near the very highest point (11,100 feet above sea level), black smoke was continuously oozing from the sandy cap. Only one bird, a junco (*J. vulcani*) was seen near the summit. The ascent, on foot, occupied 3 hours and 10 minutes, the descent being made in 2 hours. From the summit of Turrialba, as well as from that of Irazú (11,900 feet), both oceans can be plainly seen if the weather be favorable; usually, however, the Atlantic (or rather the Caribbean) is hidden by the sea of clouds which extends eastward from beneath the mountain tops across the entire land.

Most travelers in tropical countries refer to the nocturnal din produced by the combined voices of the numerous insects, frogs, toads, and other animals. As to this I must confess to disappointment. The most notable, and to one who has never heard it before the most startling, sound is that produced by the so-called howling monkey. This is also heard during cloudy days, and is really a most fearful noise, somewhat like the roar of a lion but much louder and more prolonged. It is usually produced by several animals in concert, and is plainly audible at a distance of several miles.¹⁵ At Bonilla (2,600 feet) two batrachians serenaded us nightly. One, an enormous toad, many times larger than our common species, gave concerts which at a distance reminded one of the singing at a negro camp meeting, though of course without the melody of the latter. The other was a very small tree frog, colored a brilliant scarlet or

¹⁵ Aptly described by Harry A. Franck as "like the roar of a far-off riot, like some great but distant crowd furious with anger." (Working North from Patagonia, p. 545.)

vermilion red, with feet, and spots on the under side, of steel blue. This little creature was very abundant and produced a noise out of all proportion to its size. The notes were very metallic, sounding much like strokes on the orchestral triangle, each individual having a more or less different pitch. The din was terrific until one became used to it. We called this performance the "anvil chorus." But in no part of Costa Rica did I hear a tumult of sounds such as emanate from the throats of the several species of frogs and toads during early spring evenings in parts of the United States, especially in marshy or swampy localities in the Middle West, where the combined voices of thousands of individuals of a single species (*Rana areolata*) produce a continuous roar. No owl was heard with a voice as loud or startling as the *who-who-who-are you* of our common barred owl; nor any other night bird with a more vigorous voice than our whippoorwill and chuck-will's-widow. Throughout the country, except the higher regions, the most frequent night sounds were the monotonous *kuk, kuk, kuk* (many times repeated) of a diminutive owl (*Glaucidium phalaenoides*) and the much louder and more plaintive call of the *Cuiejo* (pronounced coo-yá-ho), a species of goat-sucker (*Nyctidromus albicollis*) about the size of our whippoorwill. This sounds like a repetition of the words *coo-yá-ho; coo-coo-yáho*. At high altitudes another species (*Antrostomus saturatus*) so closely reproduced the call of our whippoorwill that the only difference we could detect was a harsh quality, or "burr," wanting in the notes of our bird.

At Bonilla we occasionally heard at night the gruff call—between a cough and short roar—of the jaguar; and once while out hunting, we saw a herd of cattle stampeded by one of these ferocious brutes, which kill many cattle on the estate.¹⁶ It is said that the jaguar never makes two meals off one of its victims but for each meal makes a fresh "kill." Whether this is really true I do not know. It is also said that the jaguar springs upon the shoulders of its prey and kills it by twisting the head with such force as to break the poor creature's neck.

While the nocturnal sounds were, to us, disappointing, there was, as compensation (and to most people a far more attractive entertainment), a nocturnal *sight* for which we in the North have no parallel. This is the splendid pyrotechnic display made by thousands of large beetles called, in Costa Rica, *Carbuncle*,¹⁷ similar in form to our so-called "snapping bugs" and resembling in size and shape that large species of the eastern United States having a pair of oval black spots upon the thorax (the general color being a dusty or finely mottled gray); but the tropical species is of a plain reddish

¹⁶ We were informed that 22 head had been killed at Bonilla in one week by jaguar.

¹⁷ Pronounced carbuncly.

brown or chestnut color and the two oval spots on the thorax instead of being superficial and black are confluent with the interior anatomy and emit a light so brilliant that one or two imprisoned within an inverted tumbler produce sufficient light to fairly illumine a room of moderate size and by which a book or newspaper can be read if sufficiently near. At Bonilla and other localities in the middle portions of the *tierra caliente* the pastures and other open places were brilliantly lighted each night by great numbers of these beetles as they flew about, a few feet above the ground. The display sometimes made by thousands of our "lightning bugs" or fire-flies over damp meadows of a warm summer night is only a feeble imitation, for the light of the carbuncle is not intermittent but nearly continuous, and differs in color in different individuals (possibly there may be more than one species), yellow in most, but sometimes green or occasionally ruby red.

It has already been remarked that, contrary to the popular impression, there are among tropical birds many songsters. Never have I heard a greater volume of bird song than on the return trip from Coliblanco to Cartago, when dozens of the common robin of Central America (*Planesticus grayi*) were singing in unison as we emerged from the forest and entered an open and partly cultivated district. This species has a song exceedingly like that of our robin but decidedly finer, being smoother and without the jerky or faltering delivery of our bird. In many instances it was noted that when a North American bird was represented in Costa Rica by a closely allied or congeneric species the song of the latter was very much finer than that of the former. The Costa Rican representatives of our robin, house wren, and summer yellow-bird or yellow warbler are conspicuous examples. A bird that was common throughout the Pacific slope, especially near the coast, belonging to the vireo family but of a genus (*Cyclarhis*) not represented in the United States, has a song like a glorified or greatly magnified bluebird's warble. But it is among the wrens, which are far more numerously represented in tropical America than in the United States, that the most remarkable songsters are found. In the dense chaparral forming the first zone of vegetation beneath the cinder-cone of the volcano of Poás, where profound silence prevails, the oppressive stillness was suddenly broken by a startling outburst of most exquisite music from some bird concealed in the thicket. The song was not only exceedingly beautiful but very loud and long continued, and in quality of tone reminded me of a Swiss music box. The singer proved to be a little short-tailed wren of the genus *Henicorhina*. Several of the wrens found only in the forests of the *tierra caliente* have songs that are no less remarkable, but to describe them would be im-

possible; it can only be said that in the United States we have nothing at all like them. Many a time, while making my way slowly and cautiously through the dense undergrowth I have been transfixed and thrilled by a sudden outburst of strange melody—as startling in its effect as the unexpected report of a gun close by—from some unseen and then unknown songster; the notes of a quality totally different from those produced by any of our northern songsters, far richer, more liquid, but at the same time strictly in harmony with the savage wildness of the primeval forest. At higher altitudes a small thrush (*Catharus frantzii*) was often heard whose song is strikingly similar in character to that of our hermit thrush, and every bit as ethereal.

The bird notes which most attract the attention of the stranger in tropical forests are not the songs, however, so much as the odd or strange calls of many species. One of the most remarkable of these is that of the Costa Rican bell bird, a bird about the size of a pigeon, uniform cinnamon-rufous in color with snow-white head and neck, and with three long, slender, flexible wattles at the base of the bill. A loud explosive *whack*, as if some one had struck a hollow log of hard and resonant wood a heavy blow with an axe or heavy mallet, is followed by a long-drawn, exceedingly loud, clear, and penetrating whistle—both easily heard at a distance of a mile or more. Probably next in order of remarkable character, and far more often heard, are the loud bubbling notes—half gobble, half sputter—of the *oropendola*, a bird of the hang-nest family but nearly as large as a crow, colored black and chestnut with tail bright golden yellow. This bird is gregarious, and the singular performances of the male are no less remarkable than his notes. Throwing himself forward until almost suspended beneath his perch, with feathers on end, the loud bubbling sound is produced, interspersed with hoots and other discordant sounds, and a rustling noise, possibly produced by friction or shaking of the primary quills. The last was compared by a native boy to the sound made by “a woman rustling her skirts.” These birds nest in colonies, their yard-long purse-like nests suspended from the tips of the branches of some isolated tree, comparatively safe from monkeys and snakes (pl. 5, fig. 1). Frequently one hears a peculiar rasping sound, as if someone were drawing the end of a stick quickly, three times in succession, across the ridges of an ordinary washboard, or the woven rattan slats of a chair bottom. This is the call of two species of toucan (*Ramphastos brevicarinatus* and *Selenidera spectabilis*); and although these two species belong to very distinct genera and are utterly unlike in appearance, I never could tell, from the sound alone, which was producing it. Another toucan (*Ramphastos*

tocard) has altogether different notes; they are pleasant to hear, being varied and not unmusical, but somewhat plaintive.

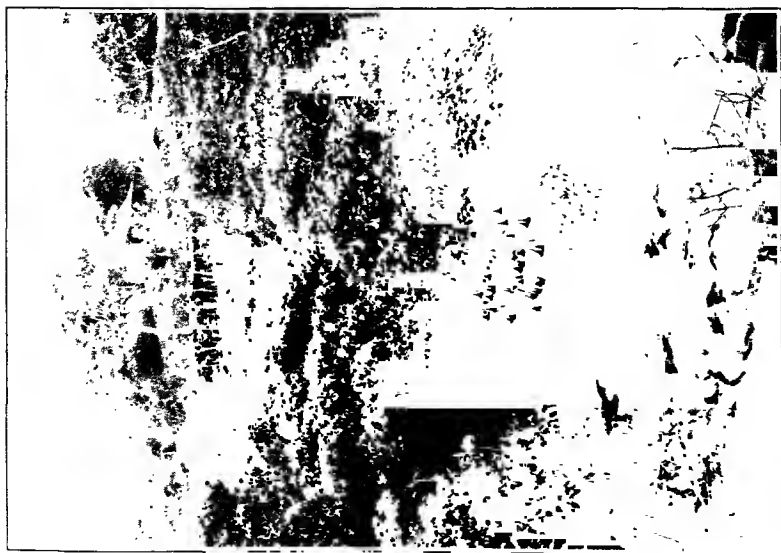
Some of the pigeons or doves also have notable calls. Once, while hunting in the Pacific coastal plain forest, near Pigres, I heard, for the first time, a sound resembling that made by blowing, at a certain angle, into the mouth of a bottle, but nearly as loud as the bellowing of a bull. I followed up the sound, expecting to find a very large bird—in fact I could think of nothing so likely as a curassow (*Crau*): but was amazed to find the performer to be a small blue-gray dove (*Claravis pretiosa*) perched on a bare branch, his crop inflated to the size of a large walnut at the time each note was produced. There are many species of doves or pigeons in the Tropics, and their calls are among the bird notes most often heard. That of one species in particular was conspicuous and was translated by the natives into *Don-pápē-féo* (pronounced pap-py-fayo, and meaning “Don Pape’s ugly”). Probably the most discordant sounds heard in tropical forests are produced by the different species of parrots, especially those large and gaudily colored species, the macaws. These are many as to species and very numerous as to individuals. At Pigres, we were so unfortunate (in a way) as to be encamped close to the roosting place of many hundreds of these birds, representing four of five species, ranging in size from the little tovi parakeet to the huge red, yellow, and blue macaw. These birds fed in the forest across the river, and, consequently, passed over our camp twice each day—on their way to the feeding grounds in the morning and back to their roosting place before dark. While preparing for their departure in the early morning and, on their return in the evening, before settling down for the night, their preparations were accompanied by much squabbling and such an unearthly squawking, screeching, and quacking, that for the time attempts at conversation were quite useless. It was a most interesting sight to see these parrots during their flight above our camp. Unlike other birds, members of the parrot tribe always fly in pairs, no matter how many hundreds or thousands may be in one flight; if one bird is seen by itself, as only now and then occurs, that bird has no mate.

Two members of the hawk tribe also are notable for their loud cries, though neither have louder calls than our red-shouldered hawk nor by any means so pleasing to the ear. The red-throated ibycter, a large glossy black hawk with white abdomen and bright scarlet face and throat, related to the caracara, roves about in small flocks, at intervals calling out loudly *ca, ca, ca, cáo*, repeated once or twice; the other noisy fellow being the laughing falcon (*Herpetotheres cachinnans*), whose cries bear some resemblance to the mirthless laughter of a demented person.

There are also many calls heard in tropical forests which are monotonous repetitions of one note. The many times repeated *kook*, *kook*, *kook*, *kook*, of the trogons is frequently heard; and at Coliblanco, and there only, we were at times almost distracted by the tireless repetition of a loud and sharp *chip*, *chip*, *chip*, somewhat like the call of the male English sparrow as he dances at the entrance to a nesting hole, trying to attract a mate, but altogether louder, more continued, and of a peculiarly piercing quality. We could never see the creature producing this call, but were informed by the natives that it was a large humming bird, of which two were common there (*Eugenes spectabilis* and *Heliodora jacula*); it may, however, have been a tree frog.

The foregoing is a mere outline sketch of tropical nature. Volumes could be filled with interesting details by one sufficiently familiar with the subject by longer residence or more prolonged exploration, for the material is inexhaustible. To the student of nature, be he zoologist, or botanist, the Tropics are full of treasures such as I have attempted in vain to adequately describe. To be appreciated in full, however, they must be seen at first hand; for "like the regal beauties of Rio they reveal themselves only to those who come to look upon them in person."¹⁸

¹⁸ Franck, Working North from Patagonia, p. 189.



1. A MOUNTAIN BROOK NEAR SAN JOSÉ.

The white trumpet-shaped flowers are 10 to 12 inches long and very fragrant, and are called *Reina de la Noche* (Queen of the Night).



2 WILD FIG TREE IN FOREST OF THE PACIFIC LOWLANDS.

Note the cart road through dense undergrowth of canas.



1. UPPER EDGE OF CLOUD-ZONE FOREST ON VOLCANO OF POÁS.

Note the masses of orchids, bromeliads, and other epiphytes on the larger trees.



2. NORTH SIDE OF THE CERRO DE LA CANDELARIA, FROM SAN JOSÉ VALLEY.

What appear to be low forests in the foreground and middle distance are coffee plantations.



1. MOUNT TURUBÁLES, FROM SANTO DOMINGO DE SAN MATEO.

This isolated mountain, 5,000 feet high, has never been visited by a naturalist. Note the similar appearance of the forest *from outside* to an ordinary hardwood forest in the eastern United States.



2. EDGE OF THE POTRERO AT COLIBLANCO.

Note the climbing bamboos.



1. OFF FOR THE DAY'S HUNT. BONILLA, COSTA RICA.



2. CINDER CONE OF TURRIALBA, COSTA RICA. FROM
NORTHWEST SIDE OF EL PARAISO.



1. IN THE POTRERO AT GUAYABO.

The large tree in the center is a *Hura*, reputed to be the tallest tree in Costa Rica. Immediately behind it are seen the pensive nests of a small colony of *Oreopodas*.



2. VOLCANO OF IRAZÚ, FROM LA SABANA, SAN JOSÉ.

Every morning during the dry season the clouds "high over" spread the Caribbean (opposite) slope crowd through the gap between Irazú and Barba, but come no farther.

THE HISTORIC DEVELOPMENT OF THE EVOLUTIONARY IDEA.¹

BY BRANISLAV PETRONIEVICS.

This historical outline must be very short, and I will only indicate in a few words the main features of the doctrines of evolution held by different thinkers. I am making this outline particularly because I wish to enable my readers to avoid the mistakes which are so often found in even the best known works on this subject. These books have been written either by philosophers who were not always in a position to really understand the meaning of the scientific doctrines of evolution, or by scientists who, on their part, were unable to thoroughly grasp the meaning of the corresponding ideas of the philosophers.

In order to make perfectly clear the simple meanings of the different theories about the origin of the world and of things in it, I must first briefly state the principal hypotheses about this origin which are considered tenable. There are four of them. The first is the hypothesis of the eternality of things, according to which the inorganic world is eternal and the organic species also eternal and unchangeable (the metaphysical systems of Aristotle and of Spinoza are the representative types of this hypothesis).

The second is that hypothesis of creation which conceives that the inorganic world as well as the organic species were created by God, but, once created, remain unchangeable (this is the orthodox hypothesis of the Church, and the naturalists. Cuvier and Agassiz are the best known sponsors of it).

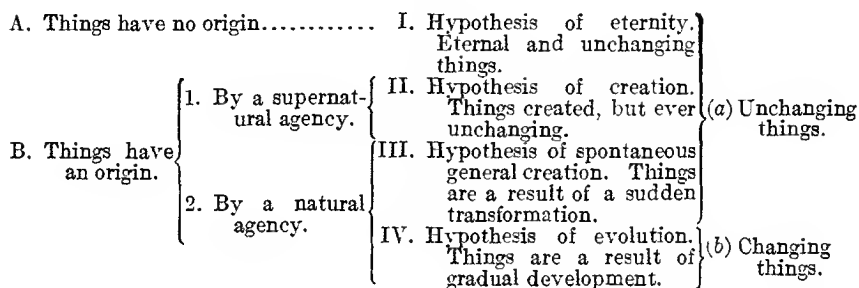
The third hypothesis is that of spontaneous general creation: namely, that the inorganic world was produced out of sheer nothingness and that organized beings were immediately formed out of a transformation of inorganic matter. (The doctrine of Buddha is the only representative of this hypothesis concerning the origin of the inorganic world, while there are several Greek philosophers—Anaximander, Empedocles, Epicurus—who teach the spontaneous generation of all organic beings, however complex.)

¹ Translated by permission from "L'Evolution Universelle," by Branislav Petronievics, of which it forms the first chapter. Librairie Félix Alcan, Paris, 1921.

Lastly, the fourth hypothesis is that of evolution, according to which the inorganic world as it exists to-day comes from a primordial state quite different from its present condition, and the organic species have been developed by a gradual transformation from inferior to superior species. (Among scientists, Laplace is the best known representative of the theory of the evolution of the inorganic world, Lamarck and Darwin, of the evolution of the organic world; among philosophers, Kant is the most noted representative of the doctrine of inorganic world evolution, and Spencer, Hartman, and Bergson of the idea of the evolution of the organic world.)

In order to make these four hypotheses more easily understood, I am placing them in a diagram which will show plainly their mutual relationships.

Diagram.



Before going further, let me name four standard works which may be consulted for more detailed study:

1. The important article of the celebrated historian of Greek philosophy, Ed Zeller, "Über die griechischen Vorgänger Darwin's," which was published in *Abhandlungen der Berliner Akademie*, 1878.

2. The work of the American paleontologist, H. F. Osborn, "From the Greeks to Darwin. An Outline of the Development of the Evolution Idea," 1894.

3. "La philosophie zoologique avant Darwin." 1885, by Edmond Perrier.

4. The excellent article, "Evolution," which appeared in the last edition of the *Encyclopedia Britannica*.

Among the different philosophical systems of India, only three deserve mention here. There is first, orthodox Brahminism, which presents the idea of emanation, by which is meant the eternality of things; then we find the system of Sankya, which combines emanation with a mechanical and evolutionistic explanation of the world; and lastly, there is the system of Buddha which is the philosophy of the spontaneous generation of the world.

Among the Greeks the germs of the evolutionistic idea are found even in the early speculations about the cosmos put forth by Hesiod

and the Orphics. But Thales is the first who clearly conceives the natural origin of the world when he teaches the existence of a primordial material from which everything is derived. His disciple, Anaximander, goes much further; he is the first declared exponent of the evolutionistic idea; he teaches the gradual development of the world from an unknown material, and a regular succession of periods of the evolution and dissolution of the universe. He also teaches the evolution of the earth, and he supposes a spontaneous generation of organisms in the water (men, themselves, first appeared in the form of fishes). Anaximenes and Diogenes of Appolonia also admit the successive periods of the evolution and dissolution of the universe; while the doctrine of Pythagoras and the Pythagoreans, although insufficiently known, seems to be that of the eternity of the world. Heraclitus adds to the idea of successive periods of evolution and dissolution of the universe, his doctrine of perpetual change. But it is in the doctrine of Empedocles that the evolutionistic idea reaches its height among the pre-Socratic philosophers. Being himself a supporter of the idea of successive periods of evolution and dissolution of the universe, he also conceives this world evolution process as going on in a mechanically causal way and he explains this as the interaction of the four elements and the two forces which unite and separate them. According to his belief, also, organisms arise from a process of spontaneous generation, but he held that it is never complete organisms which are formed, but only parts of organisms, called organs. When they unite, these parts at first form organic combinations incapable of living and propagating themselves, and it is only after a series of successive creations of this kind that organisms finally appear which are capable of self subsistence. The founders of atomism, Leucippas and Democrites, took over the essential features of Empedocles' doctrine, and perfected the mechanical side of it by their doctrine of atoms.

Finally, Anaxagoras, the last of the pre-Socratic philosophers, is the only one of these, who, while admitting an infinite number of elements all different in quality, also supposes chaos as the initial state of the world, and that this world developed itself out of chaos when it received from God the first impulsion. Anaxagoras is also the first who teaches the peculiar doctrine of the eternity of organic germs.

The teachings of Plato concerning the world and organic species, which he conceives clearly for the first time by means of his doctrine of ideas, is very little understood on account of the allegorical form which Plato generally gave to all his doctrines, and especially to his theory of the creation of the world in his "Timeon." But it seems to me that the true Platonic doctrine is a system of emanation, in which God and pure nothingness (identical with empty space and matter) are the two opposite poles.

Aristotle's system is the type of an antievolutionistic one. The inorganic world is eternal, eternally expressing the corresponding thought of the Divine Being. Although the founder of biology taught that all organized beings form a continuous ladder of degrees of perfection (from the most primitive plants to man, the most perfect animal) he conceives this ladder in a purely static manner, since the organized species were, to him, eternal and unchanging. But, on the other side, he admits spontaneous generation, even for organized beings relatively complex. A similar gradation in the domain of the mind is taught by Aristotle.

In post-Aristotelian philosophy Epicurus and his disciple, the Roman poet Lucretius, especially merit our attention. In teaching the infinity of space and of the number of atoms, Epicurus and Lucretius expressly announce that the evolutionary process of worlds has a definite beginning in time. According to them, there does not exist an evolutionary process of the entire universe, but only evolutionary processes in special worlds, separated in the great infinity of space. They conceive these evolutionary processes as taking place in a purely mechanical way, and they try to give, for the first time, a rational explanation of the evolutionary processes of the worlds. They also teach the evolution of the earth. Furthermore, in taking up Empedocles' evolutionary doctrine with regard to the organic world, Lucretius improves considerably upon this theory by teaching the spontaneous generation of entire organisms which appear in a series of beings more and more perfect. But that which most arouses our admiration for the Roman poet and makes the reading of the fifth book of his poem so extremely interesting is his theory of the evolution of the human race, of the human mind, of human society. We feel that we are here almost in the presence of a modern scientist.

Compared with Epicurus and Lucretius, the Stoics are almost reactionaries. They admit, according to Heraclitus, a periodic succession of universes, and they teach—this is their original theory—the eternity of the germs of things which develop in each universe.

The doctrine of the Neo-Platonists, Plotinus and Proclus, is the theory of the eternity of the world, which came forth by a process of emanation out of the supreme being, the pure oneness.

In the middle ages, we find in St. Augustine an allegorical interpreter of the origin of things; St. Augustine supposes that inorganic matter was created by God and given the power of self-development through its own efforts to an ordered inorganic world. He teaches in addition the eternity of the organic germs created by God. St. Thomas Aquinas accepts the doctrine of St. Augustine, although in a manner somewhat disguised.

Among the Arabian philosophers, Avicennus is devoted to the Neo-Platonic doctrine of emanation; he especially teaches, however,

the slow evolution of the surface of the earth. Averroès is an interpreter of Aristotle in evolutionistic sense. But, in general, the Arabian philosophers and naturalists are faithful disciples of Aristotle.

During the Renaissance, Giordano Bruno, although quite modern in his theory of the infinitude of the universe, does not declare himself clearly upon the question of an evolution in the universe. He teaches the evolution of the earth's surface, but he stands with Aristotle in regard to the organic world. The Jesuit, Father Suarez, is the first man who set forth in a perfectly clear manner, the doctrine of the special creation of organic species, a theory which will play an important part in the discussion of modern naturalists.

Among modern philosophers, Francis Bacon is the first to put forth the question of the possibility of a transformation in the various species, without in any way admitting sympathy with the idea of transformationism. Descartes teaches the evolution of the inorganic world (the steller system, the solar system, the earth), but he quite neglects the question of an evolution in the organic world.

G. W. Leibnitz is interesting on account of several of his doctrines. He formulated these:—1. The famous principle of continuity, which he defines in regard to the organic world in the following terms: "The different species of animals are all parts of a single chain whose links are so intimately fastened together that it can not be determined, either by observation or by imagination where one link ends and the next begins"; 2. Leibnitz teaches the eternity of organic germs; 3. He formulates the principle of an immanent evolution of the mind (from the monad); 4. He expresses hypothetically the principle of a world evolution, when he says in a passage in his "Theodicée," that it might be true, that the universe was ever progressing from good to better. In opposition to Leibnitz, the metaphysical system of Spinoza, like that of Aristotle, is the type of an antievolutionistic system, the material world and the spiritual world being both, according to Spinoza, the two eternal attributes of the divine substance.

Among the philosophers of the English empirical school we must first mention David Hume, who admits the possibility and even the probability of the doctrine of evolution in opposition to that of creation. But Erasmus Darwin, the English naturalist, goes even further than Hume; he openly takes up the theory of organic transformation and he sets forth an elaborate system of ingenious explanations. A little before him, the celebrated English geologist, James Hutton, had developed for the first time the doctrine of the slow and uniform evolution of the earth's surface.

Kant, the great creator of critical philosophy, engages our attention by several of his doctrines. To begin with, he tried to develop

for the first time in a scientific or at least partly scientific manner the doctrine of the evolution of the stellar system and, before Laplace, that also of the solar system. Then he went on to discuss the doctrine of organic evolution; but, not being able to overcome the difficulty of explaining this evolution through mechanical causes, he declared himself against it. He admitted, nevertheless, and defended the social and intellectual evolution of humanity.

Herder, a contemporary of Kant, is an even stronger supporter of the idea of evolution, although he recognizes the possibility of the intellectual and social evolution only. But even before Herder the idea of evolution and of progress had been introduced into history by the Italian, Vico, in his famous work, "*Principii di Scienza Nuova*," 1725.

In contrast to the majority of German and English thinkers, we find in France, in the eighteenth century, many philosophers and scientists who are more or less devoted to the idea of organic evolution. The celebrated astronomer and mathematician, P. L. M. de Maupertuis, is the first among modern thinkers who, in his article, "*Système de la nature: Essai sur la formation des Corps Organisés*," 1751, came out as a definite supporter of the doctrine of transformation, while he at the same time set forth the hypothesis of organic particles and of the spontaneous generation of organic life. D. Diderot follows the doctrine of Maupertuis, but he links it with the theory of organic germs and with Empedocles' teaching about imperfect organisms. However, Diderot is of some interest on account of his doctrine of social evolution. B. de Maillet teaches the metamorphosis of aquatic animals into terrestrial ones; but according to him aquatic animals come from indestructible germs. He also speaks of the slow evolution of the earth's surface, and because of this doctrine he is, like Hutton in England, a precursor of Lyell.

Ch. Bonnet is an antievolutionist. While admitting the principle of continuity held by Leibnitz he deduces from it his famous "ladder of beings." He teaches the eternality of organic germs which develop into complete organisms; each germ is merely the organism in miniature which grows only as it develops itself. (This is the theory of evolution held by Bonnet in contrast to the "theory of epigenesis.") Bonnet, in opposition to de Maillet, is also a supporter of the theory of cataclysms in the history of the earth.

I. B. Robinet admits, as Bonnet does, the Leibnitzian principle of continuity and widens its scope by formulating a "ladder of beings" which includes both inorganic and organic things. He also teaches the eternality of organic germs, but he opposes the theory of cataclysms.

Buffon begins by being an adherent of the idea of fixity of species; but later, he has a partial glimpse of their transmutability. The great Swedish naturalist Linnaeus formulates, on the contrary, the theory of the fixity of species, teaching that there are "as many species as there came couples from the hands of the Creator".

But it was in France at the end of the eighteenth century that the doctrine of inorganic evolution was elaborated for the first time in a scientific manner by the mathematician and astronomer Laplace; he, however, limited his doctrine to the solar system (in a note to his work, "*Exposition du système du monde*," 1796).

The French thinkers of the eighteenth century, Turgot and Condorcet, also hold an important place in the development of the theory of social evolution.

The great German philosophers of the commencement and of the first half of the nineteenth century were in general opponents of evolutionism. Schelling's philosophy of identity supposes in nature a series of gradations beginning in inorganic forces passing through organic beings, and finishing in self-conscious mind. But these gradations, according to him, are all in existence simultaneously. Hegel admits Schelling's antievolutionistic point of view as to nature (the inorganic and organic world)—nature being, according to his idea, the externalization of the idea, the essence of which is only a purely logical process of conceptual evolution. But in the domain of mind, Hegel expressly recognizes temporal evolution, and he is one of the most important proponents of the intellectual and social evolution. (His work "*Philosophie der Geschichte*" is a work which marks a date in the history of this evolution.) Schopenhauer is still more reactionary than Hegel; he declares himself a resolute opponent of evolution in the domain of nature (where he recognizes only degrees of objectivation of the will) as in those of the mind and of history. He also admits in geology the theory of revolutions.

Among the disciples of Schelling, on the contrary, some are declared sympathizers with the doctrine of organic transformation. First, Oken, who advances the theory of cells by his doctrine of infusorian spheres (these becoming animals in the water and plants in the air); these spheres, according to Oken, being the immediate product of the primitive jelly. Immediately after him came Tréviranus who, even before Oken and at the same time as Lamarck in France, had developed the doctrine of organic transformation (in his work, "*Biologie oder Philosophie der lebenden Natur*," 6 Bde, 1802-1822). Oken and Tréviranus were as distinguished naturalists as philosophers, and they are the only philosophers who, as original thinkers, clearly conceived and maintained the doctrine of organic evolution.

Goethe, the great poet, was never a declared advocate of organic transformation, although he discussed it during his last years under the influence of the French transformationists. E. von Baer, the celebrated founder of embryology, became, especially after Darwin, a convinced transformationist; indeed he came very near recognizing evolution as a universal process.

At the beginning and in the first half of the nineteenth century, the doctrine of organic evolution was developed by the scientists in France in a manner much more definite than in Germany. It is especially Lamarck who contributed the most to this development in his "*Philosophie zoologique*," 1809, and in some earlier essays (the first one is dated 1801). Discussing the idea of species, Lamarck directs special attention to the artificial nature of this idea; to the numerous transitions from one species to another; to the fact of varieties and the connection of these varieties with different external circumstances; to the short duration of the life of existent species so far as we can establish the stability of these species. These are the principal arguments which he presents in favor of transmutability of species. While insisting upon the slow but continuous evolution of the earth's surface, he gains a partial idea of the direct connection which exists between this evolution and that of the organic world. But it is especially in the exposition of the causes of organic evolution that the work of Lamarck presents an extraordinary originality; a part of his work which we can not discuss here.

Geoffrey Saint-Hilaire united with his theory of the unity of plan, the doctrine of organic transformism, attributing the cause of these transformations to the ambient world.

But while Lamarck and Geoffrey Saint-Hilaire represent the doctrine of transformism, the opposing doctrine, that of the creation of species, has nowhere found advocates more enthusiastic and distinguished than Cuvier and Agassiz.

When once this last doctrine had been expressly introduced into natural history by the Swedish naturalist Linnaeus, Cuvier set himself to demonstrate it by observed facts. In linking the doctrine of fixity of species to that of the successive revolutions of the globe, he taught a series of successive creations of species; but, according to him, some of these species are not exterminated by the revolutions, and there have always been migrations of some species that survived. Above all, Agassiz became the typical advocate of the creation theory, teaching that God produced, in different geological periods, organic species more and more perfect, which, once created, remained unchanged.

Auguste Comte, founder of the positivist philosophy, although a resolute advocate of the intellectual and social evolution—especially

evidenced in his celebrated law of three stages—also remained a declared opponent of organic transformation.

Finally, at the beginning of the second half of the nineteenth century, Darwin succeeded in definitely establishing the doctrine of organic transformation in his celebrated work, "Origin of Species," 1859. The arguments brought forward by Darwin in support of this doctrine are so numerous and for the most part so original that they place this scientist quite above Lamarck, and it is not at all astonishing to see that the doctrine of transformation was adopted by the scientific world only after his vigorous and decisive arguments were published. Just as remarkable as this reasoning is the theory of natural selection which Darwin proposed (at the same time as Wallace) to support his theory of the evolution of the organic world; but upon this point the principle of Lamarck is perhaps of equal importance with that of Darwin. Darwin also holds an important place in the development of the theory of intellectual and social evolution through his work on the origin of man, "The Descent of Man," 1871.

Before Darwin, the great English geologist, Lyell, definitely destroyed the theory of cataclysms in geology and introduced instead the theory of slow and continuous changes due to agents still in action to-day at the surface of the earth. But after the triumph of the Darwinian theory of transformation, the idea of evolution was definitely adopted by geologists in a more precise sense than that of Lyell.

It was only when the doctrine of organic transformation was proposed and elaborated by Lamarck and Darwin that the philosophers began to glimpse the universal importance of the principle of evolution. Herbert Spencer was the first to grasp this importance, and while giving the formula of a general law of evolution, he applied this formula to the entire field of empirical reality, and even to the totality of things in the universe, but he never tried to examine the conditions necessary to a total evolution of the world.

Ed. Hartmann was the first among speculative philosophers to set forth clearly, in his celebrated "*Philosophie des Unbewussten*," 1869, the problem of the world evolution, and while determining some of the essential conditions of that evolution, to try to give for the first time a positive solution of this problem.

Finally, H. Bergson, in "*L'Évolution Créatrice*," 1907, tried to state the principle of world evolution as identical with that of organic evolution, and with the actual duration of psychic time. Thus Bergson's doctrine is an example of a phenomenon which is not at all rare in the history of general ideas, a universal truth which has been found and elaborated according to scientific research (Laplace, La-

marck, Lyell, and Darwin are the four greatest scientists who devoted themselves to this research) ends by being proclaimed by a philosopher as, so to speak, a logical necessity.

As the present short outline of the historical development of the idea of evolution shows, this idea has been established much more by scientific research than by philosophic speculation. And while the inorganic evolution was recognized by some of the Greek philosophers and by Descartes and Kant, the idea of organic evolution was never an integral part of any of the great systems of philosophy, and no great philosopher before Darwin had recognized the general and universal bearing of the idea of evolution. It is a rather extraordinary fact that an idea of an eminently philosophic importance, such as the idea of universal evolution, should never have been recognized as such until after science had demonstrated it—this is a bit humiliating to philosophers; and it shows us that human knowledge, if it wishes to attain its total unity, must find its support and its inspiration as much in scientific research as in pure speculation.

THE HEREDITY OF ACQUIRED CHARACTERS.¹

By L. CUFÉNOT,

Professor of the College of Sciences at Nancy.

An acquired character is a modification appearing in a plant or an animal, at any age whatsoever, which is plainly the effect of an exterior and accidental cause, of such nature that if this cause had not intervened, the modification would certainly not have been produced. Acquired characters are legion. We will cite a few to fix our conception of them and to illustrate the definition: The immunity which follows an infectious disease; the sensibility to injections of equine serum which is exhibited by the Tartar peoples nourished by the milk and meat of the horse; the pigmentation of the bare parts of the human skin exposed to the action of the open air and especially of light rich in ultra-violet rays; an accidental mutilation; the modifications presented by plants of the plain when transplanted to Alpine regions; the enlargement and the strength of a muscle systematically exercised; everything which man learns during his lifetime, such as his language, his writing, any form of sport, etc. It is understood that an acquired character is just the difference between the normal condition, or the condition which served as the point of departure before the action of the modifying cause, and the new condition after the action of that cause.

In order to consider a character as acquired, it is necessary that the relation of cause to effect should be evident, either when the cause has been made to act experimentally, or when the observation of nature has been made with the care and exactness of an experiment (which is rare). It is well known that for a long time, until about 1883, it was believed without question that the acquired character was hereditary to a more or less marked degree; that is, that parents having acquired a certain thing would procreate a generation presenting more or less completely, at least in the shape of an indication or a rudiment, the acquired bodily modification, *in the absence of the exterior cause which had produced it in the parents*. Lamarck and his school made of this heredity of acquired

¹ Translated by permission from the *Revue Générale des Sciences*, Oct. 15, 1921.

characters the pivotal point of their theory of evolution and of adaptation. Darwin and Herbert Spencer also fully accepted it. It is useless to insist on the capital importance of the phenomenon for the general explanation of adaptations. Without for the moment asking ourselves why, we can see that the reactions of the individual to any exterior action whatever have very generally an adaptive or protective value: A tanned skin is less penetrable by ultra-violet rays; immunity protects against a new attack of disease; a muscle, a joint, exercised within certain limits, functions more easily and more effectively than before the training. If the heredity of acquired characters exists, to however slight a degree, we possess the key to an enormous number of adaptations. If it does not exist, we must find other explanations.

This is not alone a question which interests speculative scholars isolated from the world; it is also a question of importance to society. When it is repeated to the public at large that the practice of sports, even to excess, prepares for vigorous new generations, the idea is certainly entertained that the "all-round athletes" or even those who are abnormally specialized by exercise, will bequeath to their descendants at least a rudiment of their acquired qualities. It is surely the opinion of breeders, who believe that the effects of the training of race horses, of the good or bad nutrition of cattle, are transmissible in certain measure.

It was not until 1883 that, for theoretical reasons whose value has not been diminished by time, Pflüger,² on the one hand, and Weismann,³ on the other (Essay on Heredity, read at a public meeting when he was tendered the position of vice rector of the University of Freiburg, on June 21, 1883), were led to formally doubt this heredity. Weismann presented arguments of such force—he examined the whole question with so penetrating a critique—that it is only just to give him the credit for the change of opinion which dates from his lecture of 1883. But if he convinced many biologists, he encountered also unyielding opponents so powerful that for 37 years, in spite of numerous and remarkable researches, the heredity of acquired characters has remained a problem continually presented. It may be said that all the experimental proofs which have been contributed to the support of the transmission (E. Fischer, Standfuss, Kammerer, etc.) are mediocre and do not lead to conviction, or are susceptible of criticism and interpretations which weaken their demonstrative value, or, indeed, are frankly contradicted (as in the

² Pflüger, Ueber den Einfluss der Schwerkraft auf die Theilung der Zellen und auf die Entwicklung des Embryo, Arch. f. Phys., t. XXXII, 1883, p. 68.

³ Weismann, Essais sur l'Hérédité et la sélection naturelle, trad. de Varigny, Paris, 1892.

case of the mutilations and the experiments of Brown-Séquard). In truth the decisive experiment, verified and certain, is still lacking. As for the nonexperimental proofs, they are always subject to discussion and can never attain beyond second rank.

As it is necessary, however, to hold some opinion on a question so important that it dominates all the conceptions of evolution, we must decide for ourselves according to the relative weight which we attribute to the various arguments, and naturally each one of us holds the more strongly to his own view, the more this view allows for a greater degree of personal appreciation. Some, partisans of heredity, receive with pleasure experiments or observations, even mediocre, which seem to them to constitute proofs; others who reject it, hunt for weak points in the demonstrations, and usually find them. It is almost a matter of faith, of nationality. The great majority of French zoologists favor the affirmative, following Giard, Edmond Perrier, Le Dantec, F. Houssay, Delage, all more or less Lamarckists; the Americans, except some paleontologists, are nearly all for the negative. I am perfectly ready to admit that up to the present I have put myself on the negative side.

It is obvious that there are categories of acquired characters arising from different causes: (1) Mutilations; (2) the effects of parasitic diseases producing a general intoxication; (3) the action of the great natural factors, light, temperature, humidity, salinity, nourishment; (4) the effects of use or those of disuse; (5) the psychic acquisitions of training, of instruction. In my opinion, the negative demonstration, that of the nonheredity of acquired characters of one of these categories, is of value for that one only, and can not legitimately be extended to the others, for if there are certain acquisitions of the body which are not transmitted to the sexual cells, the bearers of the hereditary patrimony, it does not necessarily follow that the same is true for all. But, on the other hand, if there were an experiment which showed indisputably the heredity of a truly acquired character, it would be a strong probability for some other categories, for although we do not understand completely how an acquired bodily modification can add itself even in weakened form to the hereditary patrimony, if the fact were proved one single time, the argument of incomprehension would lose all of its force.

For the first category of acquired characters, it can be said that the answer is definite; since the critiques and the experiments of Weismann, many times repeated, no one believes any longer in the heredity of mutilations. Every-day observations confirm those of biologists and it is certain that the pseudo-examples of the transmission of mutilations that are quite often reported among domestic

animals and among human families are simple coincidences, which have no more interest and often no more authenticity than cases of supposed maternal impressions. The experiments of Brown-Sequard, badly done moreover, which concern the heredity of mutilations and that of physiological disorders following nervous mutilations, have been completely disproved by researches which inspire confidence, and there is nothing left of them.

Various authors have affirmed the heredity of acquired characters of the fifth category, as little likely as this seems. Here are some examples which Hachet-Souplet reports as demonstrative.⁴ A macaque monkey which he had taught, not without difficulty, to kill rats, gave birth to young who hunted rats marvelously; cats trained to respect mice had young which did not take mice, even when the distribution of their food was intentionally retarded; sparrows trained to draw a chain from a little well for six generations gave birth to young which, without training, were able to draw the same chain. A dog had been trained to make rapid pirouettes to the left; a daughter of this dog, raised in the country, having no example before her eyes and having received no training, began by herself to make pirouettes to the left toward five or six months of age. All that is very astonishing. Although one can not criticize experiments which he has not followed, I am persuaded that there is a "hole" in these observations, due perhaps to the deceit of assistants, to a surreptitious training continued unobserved, etc., and I do not doubt that the heredity of acquisitions of training will go to join that of mutilations.

The third category concerns the factors of the medium; no one doubts their determining influence on the characters of animals and plants, and it is certain that when they have been made to vary experimentally up to the extreme limits compatible with life there often result notable modifications among beings which are submitted from youth to a change of environment. But the question is to know whether these modifications pass, even in a very attenuated degree, to the succeeding generation reared in the normal medium. If they do, we have the key to the formation of geographical races and of many adaptations; for it is a fact that the results of the action of the medium would necessarily be cumulative, and after a sufficient number of generations passed in the modifying medium, the species might be very notably transformed, perhaps even irreversibly; if they do not, the effects of the medium would be produced anew for each individual, without cumulation, and the influence of the environment on the body would no longer have any interest from the point

⁴ Hachet-Souplet, *La genèse des instincts, étude expérimentale*, Bibliothèque de Philos. scient., Flammarion, Paris, 1912. P. 239.

of view of evolution. Many experiments have been made with the primary factors, as Giard calls them. Hundreds of experiments, bearing especially on insects, have given negative results as far as the heredity of acquired characters was concerned. A few only (Standfuss, E. Fischer, Schröder) have had a feebly positive result. But these are not sufficiently convincing, the authors having worked with species naturally so variable that it has been necessary to ask ourselves whether the characters which they believed to be acquired did not exist in a latent state in certain individuals before the modification of the medium. The experiments of Kammerer are still more puzzling. From 1904 to 1911 he published a great number of researches demonstrating the considerable influence of the environment on the methods of reproduction of amphibians (*Alytes obstetricans*, *Salamandra maculosa* and *atra*), on the color of amphibians (*Salamandra maculosa*) and of reptiles (*Lacerta*), and bringing into evidence in the majority of cases the transmission of acquired characters. It is not too much to say that at first glance the results of Kammerer appear incredible. He certainly had at his disposal an exceptional installation at the Prater in Vienna (Biologische Versuchsanstalt der Akademie der Wissenschaften), but that he should have been able to accomplish even with these means breedings of such great difficulty and of such long duration is indeed surprising. From the very beginning his experiments seemed too successful, too demonstrative, and too extraordinary to merit confidence. Boulenger and Bateson⁵ have criticized them severely, and there have even been mentioned trickeries and substitutions of preparations. Hans Przibram, who also worked at the Prater, has been kind enough to tell me that nothing of this sort took place, but the suspicion is at least an indication that Kammerer's results have met with a general incredulity. Argument can not then be based on them until they have been confirmed by observers in other countries, something which has not yet occurred—in fact, quite the contrary.

I limit myself to this preamble, not intending to criticize one by one the various facts presented in botany or in zoology as proofs of the heredity of acquired characters. There are many of them, but they have not withstood criticism since none of them carry conviction.⁶

Quite recently the question has taken on a new aspect with the very remarkable work of F. Guyer and E. A. Smith.⁷ It is known that

⁵ Bateson, Problems of Genetics, 2d edition, New Haven, 1916, pp. 199–211. Boulenger, Experiments on color-changes of the spotted salamander, etc. Proc. Zool. Soc. London, 1921, p. 99.

⁶ See Weismann, Essais sur l'Hérédité, 1892, and Vorträge über Descendenztheorie, Jena, 1902; Bateson, Problems of Genetics, 1916; Cuénot, La genèse des espèces animales, 2d édit., Alcan, Paris, 1921.

⁷ Guyer and Smith, Studies on cytolsins. II. Transmission of induced eye-defects, Journ. Exp. Zool., vol. XXXI, 1920, p. 171. Guyer, Immune sera and certain biological problems, Amer. Natur., vol. LV, 1921, p. 97.

when there is injected several times into the organism of a species A, crushed tissue of some particular kind coming from a different species B, the serum of A acquires the property of altering or even of dissolving the antigene B. This property of the serum may, for convenience of reference, be attributed to an antistubstance, formed by the organism A, which we shall call cytolsin. If now the serum prepared from A is injected in an animal B, the cytolsin (no matter whether it is a property or an isolable body) acts by attacking specifically in the living animal the tissues used as antigene (experiment of Bordet, 1898). Guyer and Smith chose as antigene the crystalline lens of the rabbit and the hen as the source of the antibody. Crystalline lenses of rabbits freshly killed are crushed in a mortar and diluted in the normal salt solution; the liquid is injected at intervals in the peritoneum or a vein of the hens. Several days after the last injection, the serum of one of the hens thus treated is injected in albino doe rabbits, which have been with young for from 10 to 13 days (a particularly important period for the development of crystalline in the fetuses which they contain); the injection is repeated at intervals of 2 or 3 days during a period of 10 to 14 days. The crystallolysin formed by the hen does not act on the eyes of the adult rabbits, perhaps because it does not reach the crystalline lens, unprovided with any blood vessels; but it passes through the placentas, and affects more or less strongly the fetuses inclosed in the uterus. Many die; those which survive sometimes have (9 cases out of 61 young) a lens smaller and more or less opaque (giving the eye a bluish color instead of the red of the albinos) or considerable microphthalmia, at times a complete dissolution of the eye. Without any doubt this is due to the specific action of the crystallolysin, for the control rabbits (48) coming from mothers injected either with serum from healthy and normal hens, or with serum from hens prepared with a rabbit tissue other than the crystalline lens, showed no modification of the visual apparatus. This is no longer a fortuitous coincidence due to a past unnoticed mutation, for in no race of rabbits are there known to be individuals with naturally defective eyes. So far there is nothing absolutely new or surprising for it is already known that cytotoxic serums can pass through the placenta and make an impression on the organs of the fetus. The defective eyes of the fetuses constitute a positive acquired character, for if the prepared serum had not been injected in their mothers, their eyes would have been healthy.

But this acquired character has been shown to be hereditary. It has been transmitted down to the eighth generation without any other treatment than the original injections. The transmission is quite irregular, only one of the eyes being able to be affected, but in the last generations, doubtless because the parents had been taken

by preference from among the individuals which had been the most affected, there are an increasing number of young which have both eyes affected, and the anomaly appears in an increasing number of young.

To show that the reappearance of the specific dystrophia from generation to generation is really due to heredity and not to a passage of the previously formed antibody, Guyer and Smith crossed defective males with normal females (without family relationship with the treated stock). The first generation had eyes invariably without loss (dominance of the normal character), but the females of this generation (heterozygotes), crossed anew with defective males, produced a certain number of young with degenerated eyes. From the genetic point of view, this can be understood only if it is admitted that the male hereditary patrimony has undergone a specific modification.

Of course, we can not base much on the experiment of Guyer and Smith until it has been repeated with concordant results by other observers. I will indicate later on, moreover, the criticisms which can be advanced against it. But it seems that the two authors have worked with care and have foreseen and avoided the causes of error. If this experiment is valid, what important consequences, what changes in our manner of thinking!

Since specific antibodies can produce specific modifications in the germinal cells, we can not escape the conclusion that there is in the hereditary patrimony a substance which has a certain chemical correspondence with the developed crystalline lens; the crystallolysin (be it a substance or a property) affects on the one hand the lens in process of formation in the fetus, and on the other hand the germinal cells of the same in such a way that these last will be the origin of young with defective lenses. We can understand if necessary that the crystallolysin, like a poison, might modify somewhat the germinal cell, though in a general way, like a tuberculous or syphilitic toxin or a lead poison; but that the modification should be specific is astounding. There is, then, in the germ a part which is the "representative" of the crystalline lens, for example, a fixed colloid approaching more or less the colloids of the developed lens. And if it is so for the crystalline, it should be so for all the differentiated cells of the organism, pigmentary, nervous, fat, muscular, stomachic, pancreatic, renal, etc. We thus return to a particle conception of the germinal cells, to *chemical determinants*, a theory which Delage⁸ formulated very briefly by taking up again and modifying the more or less analogous ideas of Weismann and of W. Roux.

⁸ Delage, *La structure du protoplasma et les théories sur l'hérédité*, etc., Reinwald, Paris, 1895, p. 807.

The germ would be a microcosm containing all the different colloids of the adult organism; if the experiment of Guyer and Smith is valid, I do not see how we can escape that conclusion. It contains, moreover, nothing contradictory to the Mendelian conception, for the chemical determinant or the representative colloid can very well be homologous with the Mendelian factor. In fact, Guyer and Smith show that the germinal element affected by the crystallolysin acts very nearly like a recessive Mendelian factor. When males or females with abnormal eyes are crossed with healthy individuals, not treated, coming from other regions, the progeny always appear with normal eyes (dominance); but the young are heterozygotes and contain in a dominated state the defective eye character, for if these individuals of normal appearance are crossed with rabbits with defective eyes, there appears this time among their progeny a more or less large number of young with abnormal eyes. Two individuals with defective eyes (dominated homozygotes), bred together, should produce according to the hypothesis of a simple and typical Mendelian factor, only young presenting the anomaly. If it is not always so, there is at least a striking majority with opaque or reduced lenses among their progeny. The evidence is still insufficient to see clearly into the genetics of the character. but in the main, leaving out of the question details which will probably be cleared up later, the characters normal-eye and lysis-eye form an allelomorph pair with dominance of the former.

Can it be said that the experiment of Guyer and Smith is entirely satisfactory? Far from it: an evil fate decrees that the proofs of the heredity of acquired characters never present that completeness of evidence which irresistibly entails conviction and leaves the mind at rest. Crystallolysin has a truly disconcerting action; it does not act on the lenses of the pregnant mother, a first anomaly, which, it is true, has received a more or less good explanation; it acts capriciously on the crystallines in course of development of the fetuses (9 times in 61), and according to the hypothesis, on the crystallinian determinants of the germinal cells of the same fetuses. We should then expect that it would also affect the germinal cells in the ovaries of the mother, as well as those of the fetuses. But this is not the case. The doe rabbits which survive the injections of anticrystalline serum and which have produced young with abnormal eyes are served several times by the same normal males *after the serum treatments have been stopped* (for how long a time is not known) and not a trace of ocular malformation is visible in their numerous progeny. There is in that fact something entirely incomprehensible, unless we admit that the female germinal cells can be modified only at a particular stage, that of the period of multiplication of the ovogonia,

or else of synopsis. Now it is known that among the mammals these phenomena take place in the embryo, and that the adult has only ovocytes which grow slowly and unequally and come successively to maturity. We have a means of verifying this subsidiary hypothesis, for adult males present all phases of spermatogenesis, from spermatogonia to spermatozoid. By injecting anticrystalline serum in males, their sexual cells should be affected at the sensitive stage, and, mated later with normal females, they should transmit the anomaly, which would be visible only among their grandchildren. It is a crucial experiment; I do not see that Guyer and Smith have tried it.

It would be better, in order to simplify the experiment, to use not merely the hen as the source of crystallolysin, but rather the rabbit itself, in this way not introducing the foreign factor, the hen serum. However, Guyer has recently succeeded in obtaining a young rabbit with two defective eyes by injecting several times in the normal mother crushed crystalline lens of rabbit before she was with young and during her gestation. A rabbit can, then, form a crystallolysin as efficacious for the rabbit as that produced by a foreign species.

Thus we have been led to admit, in order to interpret the results of Guyer and Smith, that the crystalline lens has some representation (it matters little how we understand the word and the thing) in the germinal cells, since the specific antibody acts upon them specifically. Now, the crystalline is indeed the last organ which we should expect to see represented in the sexual elements. Beautiful researches conducted, it is true, on fish and batrachians tend to lead us to consider⁹ the crystalline lens as the epigenetic organ par excellence, as a reaction of the epidermis in contact with or in the vicinity of the optic cup; when the latter comes in contact with the epidermis at any point whatever (abdomen, mouth, dorsal face, etc.), it develops a crystallinian thickening. It is not necessary, then, to believe that the crystalline is "represented" directly in the hereditary patrimony, since it is enough that the optic cup be represented in order that there may be formation of crystalline. This is, however, only a difficulty.

Let us come back to acquired characters. The experiments of Guyer and Smith, while admitting that they should be confirmed in fact and interpretation, will permit us to accept henceforth the heredity of characters acquired under the influence of the great general factors of the medium. At the same time that these produce their more or less adaptive effect on certain tissues of the

⁹ See Werber, Critical notes on the present state of the lens problem, *Biol. Bull.*, vol. XXXIV, 1918, p. 219. Fessler, *Zur Entwicklungsmechanik des Auges*, *Archiv. für Entw. der Org.*, vol. XLVI, 1920, p. 169.

body, they modify in a parallel sense the representative colloids of the germinal cells, so that there would be a cumulative effect of the same general factor acting on successive generations. It is just this which has been supposed for a long time by Weismann himself and which has been designated by the name "parallel induction" (term of Detto). Weismann¹⁰ has illustrated the fact by the celebrated example of *Chrysophanus phloeo*s. This butterfly of very wide geographical distribution varies according to the seasons and to localities: In northern regions, the upper wings are golden red with a black border and black dots on the disk, the posterior wings blackish with a reddish submarginal band. In southern Europe there are found in the summer generation larger specimens whose two pairs of wings are almost entirely black (form *eleus*), with all intermediates between this form and the type. If caterpillars coming from eggs of *phloeo*s from Naples are raised in Germany and the pupae submitted to a low temperature (10° C.), there develop butterflies a little less black than those of Naples, but much blacker than the German ones; on the contrary, pupae of German origin submitted to a high temperature (38° C.) produce butterflies which are a little less fire-red and a little blacker than the ordinary German butterflies.

The hereditary character of the southern varieties, an abundance of dark pigment, is thus seen to be directed in the same way as the action of the higher temperature. We can suppose that when the species, at first northern, reached the south, the rise in temperature affected, with a like result, the formative elements of wing color, and the colloids representative of the pigment in the germinal cells. Hence the present condition.

We can perhaps accept the heredity of immunity, an acquired character appearing after a germ disease; not total immunity, for we know well that this is not transmissible, but a partial immunity which is sufficient, without need of recourse to a selection of the most resistant, to explain why the inhabitants of a country where a disease commonly occurs are generally more apt to resist it than those of a country which is free from it, and that diseases which are brought into new countries cause there terrible ravages. Guyer reports that rabbits inoculated successively with typhoid vaccine, then with living typhoid germs, can transmit to their young and even to the following generation the property of agglutinating the typhoid bacilli in the dilute serum (this is, however, in contradiction with previous researches on the transmission of immunity and demands confirmation; do not the mothers remain bearers of bacilli of weakened virulence which, expelled periodically, would induce a

¹⁰ Weismann, Vorträge über Descendenztheorie, Jena, 1902, p. 306.

mild infection of their young? From this fact, the latter, becoming immune in their turn, would be capable of agglutinating the typhoid bacillus and even of transferring their immunity to the second generation).

Thus we begin to see, taking as a basis the experiment of Guyer and Smith, that we will be able to understand and admit the heredity of certain characters acquired through nonuse or even through use, a question which places in wide opposition the Lamarckist school and the mutationist school. It may be that an organ affected by individual nonuse (the eye, for example, of an animal living in total darkness) produces specific modifications in the body fluids, a kind of lysis, if you wish, which would affect the representative substances in the germinal cells, and would lead gradually to the hereditary atrophy of the organ.

I sincerely hope that the experiments of Guyer and Smith may be done again more rigorously, in order to put an end to the discussions on the heredity of acquired characters and the intimate constitution of the hereditary patrimony. Only then will it be possible to build on a solid foundation a theory of the evolution of living beings.

BREEDING HABITS, DEVELOPMENT, AND BIRTH OF THE OPOSSUM.¹

By CARL HARTMAN,
The University of Texas, Austin.

[With 10 plates.]

In the popular mind, the generation of no animal is so shrouded in mystery as that of the opossum. Throughout the country, among both whites and negroes, deeply rooted tradition has it that the opossum copulates through the nose and that the female blows the fruit of conception into the pouch. Other myths relating to details of the reproductive process in this species are current among the people.

The growth of such legends need not surprise one, however, for the early birth of the embryos and the use of the pouch as an incubator certainly challenge the imagination. These phenomena attract the attention because they are unique, differing from the familiar method of rearing the young obtaining among the higher mammals, including man. Familiarity breeds contempt; the ordinary ceases to be marvelous. Thus on account of its rareness and its "different" character the opossum, our only marsupial, figures in the folklore to a prominent degree.

As a matter of fact, however, in extenuation of the popular misconception alluded to, it must be said that extremely few scientific observations upon the breeding habits of this animal are recorded. For example, there seem to be only two observations on the mating habits of this species, one by Dr. Middleton Michel (1850), an American physician, and the other by Selenka (1887), the German embryologist. Likewise, the birth of a marsupial, whether American or Australian, was seldom observed: and until the writer in 1919 witnessed the actual passage of the young into the pouch the method of transfer remained an enigma even to the professional zoologist. Little published data existed, therefore, to refute myth and legend.

The present paper is an attempt on the part of the writer to summarize some of his observations on the reproduction of the opossum.

¹ Contribution from the Department of Zoology, The University of Texas, No. 154.

His studies on the embryology of this form were begun eight or nine years ago at the instance of Prof. J. T. Patterson, following the appearance of Prof. J. P. Hill's beautiful monograph on the early stages of *Dasyurus*, the Australian "native cat." Notes were taken for various purposes on 685 female opossums and a complete series of several thousand eggs, embryos, and pouch young was collected. The work on so large a scale was made possible through liberal grants from the Wistar Institute of Anatomy and Biology (Philadelphia) and a \$500 fund given by Mr. H. A. Wroe, of Austin, Tex., in 1920. Although the original interest centered around the development of the embryo, observations and experiments were made upon the physiology of reproduction. This paper will deal with both topics.

SPECIES STUDIED

Almost all of the experimental animals belonged to the species *Didelphys virginiana*, of which there is a gray and a black phase. These apparently occur in the proportion of about 10 to 1, respectively. The color depends entirely upon the color of the overhair, which is white in the gray phase, black in the black phase. Three albino and three cinnamon mutations have also been acquired, the latter a gift from Dr. Charles McNeil, of Sedalia, Mo., where the brown form is said to occur rather often. It would seem that the same factors underlying hair color are widespread throughout the mammalian series, including the marsupials.

THE FEMALE REPRODUCTIVE ORGANS.

Before going on to the main subject it is essential that the reader be familiar with the anatomy of the reproductive organs of the female opossum. The generic name *Didelphys*, given to the opossum by Linnaeus, has reference to a distinctive feature of marsupials, namely, the presence of two separate and distinct uteri (fig. 5, pl. 2; and pl. 3); for in the higher mammals there is but one, which may, however, be divided into the central "body" and the two "horns." Each uterus opens by a separate "os," not directly into the vagina but into a lateral vaginal canal; and the two lateral canals in turn, after describing a loop, empty separately into the median vaginal canal or vagina proper. This opens with the rectum into a short "cloaca," so that there is in marsupials but one external opening ordinarily visible posteriorly, namely, the cloacal orifice. It is thus seen that in marsupials the paired arrangement of organs obtains not only for ovaries and Fallopian tubes, as in all mammals, but also involves the uteri and the lateral vaginal canals. From the standpoint of their physiological behavior the lateral vaginal canals

are a part of the vagina, since the oestrous changes in the organs are identical. Parenthetically it may be pointed out that, in adaptation to the paired lateral vaginal canals the glans penis of the male is bifurcate. The spermatozoa, to fertilize the eggs, must travel through the canals and the uteri to the Fallopian tubes, where fertilization takes place. At birth, however, strangely enough, the fetuses do not follow the lateral vaginal canals to the exterior but break through a "short cut" to the median vagina, as shall appear below in the section dealing with parturition.

In spite of the paired condition of the uteri the eggs of both sides are simultaneously fertilized—if sperms reach one tube they reach both. Among several hundred pregnant specimens scarcely an exception to this rule has been found.

THE OPOSSUM AS AN EXPERIMENTAL ANIMAL.

The possession of two distinct uteri renders the animal ideal for securing accurately timed developmental stages. To do this one uterus is removed under anesthesia and aseptic conditions and the stage of the contained eggs or embryos ascertained. The intact uterus then serves as an ideal incubator for the remaining eggs, which are allowed to develop for a calculated length of time. This technique is one of the factors which have enabled the writer, assisted by Dr. C. H. Heuser formerly of the Wistar Institute, in several weeks of 1917 to secure a nearly complete series of stages. The method may, of course, be used with other mammals, e. g., the rabbit, as Bischoff did nearly 100 years ago; but inflammation is likely to obscure the results where the horns of the uterus are successively ligated.

To illustrate the application of the method, several sets of eggs are shown in plates 4, 5, and 6. Some of these are discussed below under the heading "Period of gestation." Suffice it at this point to direct attention to two cases. The eggs of animals Nos. 560' (fig. 11, pl. 4) and 582' (figs. 24 and 25, pl. 6) had arrived at the identical stage when the animals were killed. Two of these eggs are shown in detail in figure 21, pl. 6. Now No. 582' had developed in 66 hours from 0.75 millimeter vesicles (fig. 20, pl. 6); No. 560' in 18 hours from a primitive streak stage (fig. 13). It is thus relatively easy to secure almost any desired developmental stage.

There are other reasons, important to the physiologist, which make the opossum an interesting object for experimentation. For example, because of its early birth, the study of the opossum must needs contribute its share to the final analysis of the cause of birth. In this species, furthermore, there is no structure that may be called a placenta; hence those who make much of the rôle of the placenta as an organ of internal secretion will do well to check their results by

referring to the aplacental marsupials. Again, as is well known, when once attached to a teat, the pouch young must remain attached until ready to leave (about two months); hence only the occupied teats are suckled by a given litter of young, whereas in other mammals first one, then another, hence all of the teats are used and all develop. Here, then, a simple observation is all that is necessary to show that suckling is the stimulus which causes the glands to continue their growth during lactation. This purely local effect is seen in figure 45, plate 10, which represents a section through four occupied and two unoccupied (*a*) mammary glands.

These examples must suffice to show that a study of a "different" animal is not only interesting to the lay public because it is relatively rare, but also proves to be of value to the physiologist because of the sidelights which its study may throw upon the theoretical phases of his subject.

THE DIAGNOSIS OF PREGNANCY IN THE OPOSSUM.

There are certain other observations which have facilitated the collection of embryos. It has been found possible to diagnose pregnancy with practical certainty and even the stage of pregnancy with a fair degree of accuracy. This method is by palpation of the mammary glands. Towards the first of the breeding season the skin of the pouch containing the resting glands begins to swell and to take on a certain firmness and turgor. By feeling of the animals on successive days one may select from among hundreds only the pregnant ones, leaving the others. Œstrus may, however, also be diagnosed by Stockard and Papanicolaou's vaginal smear method, as will be seen below.

THE OPOSSUM IS POLYŒSTROUS.

The opossum is polyœstrous; that is, it has more than one œstrus or heat period during a given breeding season. A female may have two (or perhaps, in rare instances, three) litters a year, and this plurality of litters alone classifies it as a polyœstrous animal. If, however, at the first œstrus impregnation does not take place or if the embryos die in utero, which seldom happens, or if the pouch young are removed or lost, the female will sooner or later come into heat again. The writer has removed pouch young many times. The interval between such removal and the onset of a new œstrus is found to be extremely variable, depending as much on the condition of the female as on any other factor. In general, the older the pouch young, the shorter the interval; for with the growth of the suckling young the ovarian follicles also develop. Indeed, there are several records of lactating females almost at the stage of œstrus

and in a few instances uterine eggs were recovered as early as five days after removal of the young. Such findings might give color to the statement of some authors that a single female may carry two litters of different ages at one and the same time. But for reasons which will be stated below such "superfetation" in the opossum is unlikely if not impossible.

THE ŒSTROUS CYCLE.

The writer has also followed some scores of individuals through the œstrus cycle and has determined that there is no fundamental difference between the opossum and the higher mammals in the various phenomena accompanying the cycle. For several seasons the changes occurring in the mammary gland as diagnosed by palpation were followed. As heat approaches the glands swell and become firm; and after ovulation, whether pregnancy ensues or not, the mammary gland continues its rapid swelling and turgescence for five or six days.

This statement has two important implications. First, ovulation in the opossum is spontaneous, that is, copulation is not necessary for the dehiscence of the follicles as is the case in the cat and probably some other mammals. Second, whether the eggs are fertilized or not, the reproductive organs develop up to a certain point, probably under the stimulus of the corpora lutea; and this statement holds for the uteri, the lateral vaginal canals and the vagina as well as for the mammary glands (cf. figs. 8 and 9, pl. 3). This striking development of the organs outside of pregnancy has been termed by Professor Hill the stage of "pseudopregnancy." This stage is pronounced in the marsupials; but as Ancel and Bouin and Long and Evans have shown the stage is also manifested to some degree in the rabbit and the rat.

If pregnancy ensues, the uteri and the mammary glands continue their growth and development, the uteri till birth, the mammary glands for about two months (fig. 45, pl. 10). But pseudopregnancy may be distinguished from pregnancy after the sixth day by regressive changes in the mammary glands, which become flaccid and gradually thinner so that several days before the next heat they are almost as thin as in the resting stage.

Thus the cycle was established and found to be about a month in duration.

For the last two seasons the cycle was also followed by the aid of Stockard and Papanicolaou's method of studying smears of the cell content of the vagina. By this method, also, a distinct rhythm was observed quite comparable with that shown by Stockard and Papanicolaou for the guinea pig and by Long and Evans for the rat.

At the onset of œstrus, when the ovary contains ripe follicles, the vagina is greatly swollen and the lateral vaginal canals are distended to enormous proportions by a clear, thin, stringy mucus. Indeed this swelling of the lateral vaginal canals as the ovarian follicles reach medium to full size is a most striking phenomenon—the canals may even greatly exceed the uteri in size (fig. 7, pl. 2). After ovulation they rapidly retrogress and become filled with a dry cheesy mass of epithelial débris. Since there is probably a considerable delay between œstrus (copulation) and ovulation, it is likely, as Hill has suggested, that these canals serve as receptacula seminis.

In studying the vaginal smear of the opossum there is one complication which somewhat masks the picture shown. In the higher mammals the presence or absence of white blood cells is diagnostic for certain stages in the cycle; but in the opossum the cloaca and the vagina are often filled with corpuscles from the anal glands (scent glands?); and since these corpuscles simulate white blood cells it has thus far been impossible for us to use the presence or absence of these cells from the smears to diagnose any particular stage of the diœstrous cycle.

To recapitulate, then, if a female opossum is kept isolated from males there recurs throughout the breeding season a succession of œstrous cycles about a month in length. These cycles may be followed without injury to the animal by simple palpation of the mammary glands or by the study of vaginal smears.

THE BREEDING SEASON.

The breeding season of the Virginia opossum begins in January at Austin, Tex., and probably several weeks later in the North. A few individuals may come into heat in the first week of the year, but more enter this condition the second week. In the third week the season is at its height; hence the embryologist desirous of securing eggs and embryos would best time his collection during the last week in January and the first week in February. The prevailing weather seems to have no effect on the onset of the breeding season.

By the middle of February most females captured have young in the pouch. But late in the spring and in the summer there is great irregularity in the condition of the females, so that one may capture females with small young in the pouch any time between May and September. Many reasons may be advanced for this variability: accidents to the mother resulting in early loss of the young; variability in weaning age; condition of the female, the robust reproducing faster than the weak; age of the animals, the very youngest "yearlings" and the oldest multiparæ being the latest to come into heat.

REPRODUCTIVE PERIOD AND THE SPAN OF LIFE.

As has just been stated, the opossum breeds the first year—"yearlings" have furnished the writer with some of his best material. The weights of pregnant females range from 651 grams to 2,200 or even 2,600 and 2,800 grams, averaging 1,337 grams; in other words, they continue to grow very considerably after becoming sexually mature. On this basis, from a rough calculation based on a hundred records of size and weight, it would seem that the opossum lives at least seven years. What the reproductive period is, that is, the number of years that the opossum may bear young, it is almost futile to estimate. However, many very old females with greatly dilated pouches are annually brought to the laboratory. Some of these animals have doubtless passed the menopause because after months of feeding they fail to show any sexual activity and on killing them their ovaries and uteri are found to be of infantile size. It is quite possible, therefore, that even in nature some individuals actually die of old age.

NUMBER OF LITTERS PER YEAR.

The number of litters a year is stated by Audubon and Bachman (1850) to be three, and this statement is currently copied in various descriptive accounts. Certain considerations have led the writer to question the correctness of this statement. First, most writers underestimate the length of time necessary to rear a litter of young. The attached stage of the pouch young is given as one month, which is less than half the actual time. For Doctor Meigs observed one litter attached for 72 to 74 days; and the writer can state definitely that the period is certainly not less than 65 days. Thus, if one add to this the period of gestation of 11 days and an additional month in which the young move freely about but still suckle, it is seen that a litter can not be reared in less time than three and one-half months. One must, furthermore, allow several weeks for the greatly enlarged teats to retrogress before the birth of a new litter; for it is manifestly impossible for newly-born young to attach themselves to any but very small nipples (cf. fig. 6, *a*, pl. 2, and fig. 45, pl. 10). Finally, during November and December all females that were ever brought into our laboratory were in the resting stage; that is, in *anæstrus*. The calendar year of 12 months does not, therefore, allow enough time to rear more than two litters of young with the possible exception of an unusually vigorous female that begins breeding at the end of December and continues uninterruptedly until the following November.

MATING.

As has been stated above, the act of copulation in the opossum has twice been described in the literature. On this point it is not neces-

sary to go into details here, suffice it to say that it occurs as in other mammals with the exception that during the act both male and female lie on the right side, once the male has attained a hold with his legs about her body and with his teeth upon her neck.

Both before the female comes into heat and after she passes out of that stage she is extremely combative. The writer has seen a tiny female all but kill a husky male, thrice her weight.

When a female is in œstrus the courting male makes a peculiar clicking sound with his tongue or teeth. The sound has an almost metallic ring. It is described by Selenka as "ein schmatzender, schnalzender Laut." Females never make the sound and males only at the time of mating. Recently Jones published a paper "On the Habits of *Trichosurus vulpecula*, the Australian 'Opossum,'" in which he says:

During the breeding season, when fights are most common and animals are most vocal, the male produces a curious sound like a sharp licking of the lips and a click of the tongue. So far, I have not heard a female produce this sound.

It is possible, then, that this clicking sound of the sexually excited male is a point of behavior which is confined to the class Marsupialia, hence may be considered a class character as much so as an anatomical or structural peculiarity confined to the class.

THE PERIOD OF GESTATION.

In most mammals ovulation follows immediately or soon after copulation; hence the time between copulation and birth is practically identical with the period of gestation. In marsupials, however, it seems that ovulation is greatly delayed. This refractory period has been designated by Hill as the "postœstrous period," the time between copulation and ovulation. The data so far as collected serves to show that the postœstrous period is of considerable length and is a variable quantity. It is largely because of the varying length of this period that the exact length of gestation of no marsupial is definitely known.

To illustrate the variability of the postœstrous period, Hill's (1913) study of *Dasyurus* may be cited. This author found 2-celled eggs four, five, and six days *post coitum* or as the figures may be interpreted, ovulation took place two, three and four days *post coitum*.

Similar data hold for the opossum. Selenka gives the period at "exactly five times 24 hours"; but he bases his figures on the finding of eggs in "cleavage," which were really fragmenting, unfertilized eggs. Between three and four days is nearer the truth. The writer has recovered young opossum vesicles of identical stage from two females (Nos. 298 and 314) 6½ and 3½ days respectively *post coitum*.

the former almost double the latter. To make another comparison, our No. 114 yielded embryos of 8-10 somites eight days after copulation while No. 343 furnished only 1 mm. vesicles (fig. 36, pl. 8) in about the same time, a calculated discrepancy of nearly three days.

Figures on the total period between copulation and birth show the same discrepancies. Thus Hill gives one case of parturition 8 days, one of 16 days and a third of 20 days after the last copulation. Selenka's opossum gave birth 12 days, 20 hours after copulation. With this the single specimen which the writer allowed to come to term closely agrees.

RATE OF DEVELOPMENT.

The writer has, however, considerable data on the rate of development, inasmuch as two stages were secured from each of a large number of females. Thus, from No. 306 2-celled eggs were taken at a given time from the left uterus and 116½ hours later 1 mm. vesicles were taken from the remaining uterus. No. 360 yielded 1 mm. vesicles from the left uterus and 70 hours later embryos with small allantois, about three days of term, were removed from the surviving organ. Adding these periods together we have a total calculated period of gestation of about 11 days.

Similarly the eggs of our No. 293 developed in 3½ days from the 4-celled stage (fig. 14, pl. 4) to vesicles (fig. 15), about a half day more advanced than the first eggs taken from No. 585 (fig. 16, pl. 5); and these in turn developed 5¾ days longer, arriving at the stage of embryos about 2½ days of term (fig. 17, pl. 5). These periods likewise total between 11 and 12 days. Longer intervals are represented by Nos. 342 and 561. In the former, 30- to 50-celled eggs became embryos about 3 days of term in 7 days; this record indicates 11 days as the approximate period of gestation. In the case of No. 561, Figures 18 and 19 (pl. 5) represent 7½ days of development. This points to about 10 days as the period of gestation.

From the data thus far in hand it appears that 11 days is very near the average period of gestation. The possibility is not excluded that this period varies somewhat and that the variability in the time between œstrus and birth is to be explained in the varying length of both the postœstrous period and the period of gestation.

PASSAGE THROUGH THE FALLOPIAN TUBE.

Twenty-four hours or a little less are required for the eggs to pass through the Fallopian tube. This estimate was first made on the basis of the rate at which the albumen is deposited; later this was found to be substantially correct through a successful attempt to "mark" the eggs. Into the body cavity of female No. 566, which had just ovulated, were placed several score of *Ascaris lumbricoides*

eggs. One of these became enclosed in the albumen of an opossum egg (*a*, fig. 29, pl. 7) where it was found 24 hours later when the uterus was opened.

The general course of development may now be briefly outlined.

THE EGG ENVELOPES.

In the Fallopian tube the spermatozoon enters the egg and fertilization takes place. The albumen is then laid down about the ovum, being deposited in layers (figs. 27, 28, and 33, pls. 7 and 8) and attaining a considerable thickness (figs 35 and 37, pl. 8.). Finally around this there is added the shell membrane which characterizes the egg of marsupial mammals (*sm*, figs. 26 to 28, pl. 7). These egg envelopes, of course, are homologous to albumen and shell membrane of the bird's egg; marsupials are the highest mammals in which they are present as vestigial structures. The writer has advanced the theory that the shell membrane serves a useful purpose in insulating vesicles from each other, for in later stages they are very closely and tightly packed together in the uterus. The shell membrane may thus serve to prevent the fusion of the chorions and the possible production of sterile individuals ("free-martins"). The shell membrane is at any rate a most remarkable structure: It is devoid of cells yet it grows in thickness and a thousand or more times its original area.

Sometimes two ova are inclosed by the same egg envelopes; this results in a 2-yoked egg (figs. 30-32, pl. 7), as often seen in hen's eggs. Since only eight such cases have been found among some thousands of eggs, double-yoked eggs must be very rare. This raises an interesting question as to the mechanism by which the eggs are distributed in the Fallopian tube so as normally to prevent their inclusion together in the same egg envelope.

CLEAVAGE.

Cleavage begins in the uterus. In this particular, marsupials differ from other known mammals, for in these the egg undergoes segmentation in the Fallopian tube attaining at least the 2-celled stage, more often the morula stage, before reaching the uterus.

The 4-celled opossum egg shows an arrangement of cells much as in the higher mammals (fig. 26, pl. 7).

The further cleavage of the marsupial egg differs from that of other mammals in the absence of the morula or mulberry stage; for as the cells multiply they arrange themselves from the start in the form of a hollow sphere (figs. 27 and 28, pl. 7). This may already be seen in the 16-celled stage. When the 50-celled stage is reached the ovum is a completed vesicle, a perfect sphere; it is hollow, except for the excess of yolk which characterizes the marsupial egg. The

yolk mass affords another particular in which the egg harkens back to its yolk-bearing Sauropsidan ancestors. To attain the vesicle stage requires about 40 hours of development.

CELL-LINEAGE.

Recurring a moment to the 16-celled stage it may interest the reader to know that Prof. Hill, in his study of the Brazilian opossum, *D. aurita*, showed that the 16 cells are divided into 8 slightly larger and 8 smaller cells. Doubtless one group develops into the embryo; the other into accessory structures of use only in fetal life (trophoblast, chorion). Professor Hill thus corroborates the present writer's theory that the embryo arises from only one of the first two cells of the 2-celled stage, the other cell developing into the accessory and temporary structures.

FORMATION OF ENTODERM AND GROWTH OF VESICLE.

At the 50-celled stage the entoderm begins to differentiate. Certain cells in the upper half of the vesicle swell and drop below the level of their fellows into the lumen of the vesicle (fig. 33, pl. 8). Here they multiply; and as the vesicle grows they spread out under the outer layer to form the entoderm. The vesicle grows and becomes progressively more thin walled (figs. 34 and 35, pl. 8). Soon the entire vesicle is lined with the thin flat entoderm (fig. 37, pl. 8). At this stage, then, the vesicle is a double wall. It is now 0.8 mm. in diameter and 4½ days of development have passed. There is still some albumen left at the pole opposite the embryonic area (fig. 37, pl. 8). This area occupies only about one-sixth of the surface but it is the thickest and densest portion of the wall.

FORMATION OF MESODERM.

This "bilaminar" or two-layered vesicle continues to grow for another day without much change. Soon after the beginning of the sixth day cells may again be seen dropping out of the superficial layer of the embryonic disk to take their place between the two layers. These cells are the first mesodermal cells. They appear in a definite group toward the margin of the disk (*m*, figs. 39 and 40, pl. 9). Soon the primitive streak is clearly laid down and the embryo may be said to begin to take shape. Nearly half of the embryonic life is passed—in six days the embryo will be born a "chylopoietic, warm-blooded, oxygenating, innervating, free-willing" mammal. (Meigs.)

IMPLANTATION.

At first the eggs are usually found toward the cervix uteri somewhat scattered among the delicate folds of the soft mucous membrane

(figs. 10 and 12, pl. 4). As the vesicles grow they become more evenly distributed in the uterus. Eventually they become greatly crowded in the uteri and become jammed together under great pressure.

The vesicles are never attached to the uterus wall, there being no placenta. Up to the time of birth it is easy to separate chorions from the uterine mucosa with a brush, taking out the vesicles intact. But the chorions are in very intimate contact with the mucosa and follow it over every fold and down every furrow. Here the nutritional exchange between mother and fetus takes place; and this is quite sufficient for a few days of fetal life. These relations are well shown in figure 44, plate 9, which is taken from Selenka.² The illustration shows two closely applied vesicles. In one the allantois only is seen; in the other the posterior end of an embryo also. The chorion is represented as pulled away from the uterine wall at the upper margin.

NUMBER OF EGGS, EMBRYOS, AND TEATS.

Hill has called attention to the overproduction of eggs in *Dasyurus*; and since the same phenomenon is seen in the opossum the following quotation from Hill's paper (1911) is of special interest:

Dasyurus breeds but once a year, the breeding season extending over the winter months—May to August. One remarkable feature in the reproduction of *Dasyurus* is the fact that there is no correlation between the number of ova shed during ovulation and the accommodation available in the pouch. The normal number of teats present in the latter is six, though the presence of one or two supernumerary teats is not uncommon; the number of ova shed at one period is, as a rule, far in excess of the teat number. I have, for example, several records of the occurrence of from 20 to 25 eggs, two of 28, one of 30, and one of as many as 35 (23 normal blastocysts and 12 abnormal). There can be little doubt that *Dasyurus*, like various other marsupials (e. g., *Perameles*, *Macropus*, etc.), has suffered a progressive reduction in the number of young reared, but even making due allowance for that, the excess in production of ova over requirements would still be remarkable enough. Whether this overproduction is to be correlated in any way with the occurrence of abnormalities during early development or not, the fact remains that cleavage abnormalities are quite frequently met with in *Dasyurus*.

The average number of eggs shed by an opossum at ovulation is 22, or 11 from each ovary. Cases of 30 and 35 eggs are not uncommon; and the records run up to 43 eggs. Indeed, if one ovary is removed the other increases its activity to compensate for the loss. Thus in four cases single surviving ovaries yielded 30, 40, 43, and 44 eggs.

² The opossum embryo at various stages has been beautifully and correctly figured by Selenka in his *Studien ueber die Entwicklungsgeschichte der Thiere*. IV, Das Opossum, Wiesbaden, 1887.

It must not be supposed, however, that all of the eggs develop. Indeed, about 10 per cent of the eggs found in the first half of gestation are defective, the majority of which are actually unfertilized. Such moribund specimens may be seen among the normal eggs in figures 31 and 36, plates 7 and 8.

In spite of the progressive mortality of eggs and embryos in utero it happens that very often more young are born than can be accommodated by the 13 teats in the pouch. The writer has records of 18 and 21. The excess is, of course, doomed to death by starvation.

NUMBER AND ARRANGEMENT OF THE TEATS.

As just indicated, most female opossums have 13 teats. Of these 12 are arranged in the form of a horseshoe with 6 teats on each side, the open side of the horseshoe forward. The odd teat is in the center opposite the third teats, counting from the posterior end (fig. 47, pl. 10). $6+1+6$ may therefore be used as the formula to designate the usual number found. Just what proportion of animals have this number is not known. Certain it is that many animals vary from this number. The writer made no pretense to gather complete data on this subject; but a perusal of his cage notes yield the following figures:

Number of teats.	Arrangement.	Number of animals.
11	5+1+5	2
11	6+1+1	1
12	6+1+5	3
13	7+1+5	1
13	6+1+6	22
14	7+1+6	11
15	7+1+7	1
16	7+2+7	1
17	8+1+8	1

NUMBER OF YOUNG TO THE LITTER.

Although 13 or more teats are usually recognizable in the opossum pouch it is extremely rare to find them all occupied. Still more rare is a number above 13. The writer has never seen more than 13. But in the files of the Biological Survey there are two authentic records of 14 pouch young. One of these was recorded in R. J. Thompson's Field Catalogue and relates to a Virginia opossum found in Tennessee, June 23, 1892. The arrangement of teats is sketched in the notes and is $6+2+6$. The other record is found in the E. W. Nelson-E. A. Goldman Field Catalogue of Mexican opossums. The specimen with "14 young in pouch" was taken at Oaxaca, June 25, 1895.

In this connection a case that came to the writer's attention is of interest. In May, 1921, a young hunter excitedly telephoned the writer that he had an opossum "with 25 young." The next morning this number had dwindled to 12. But the animal was actually taken with double this number. These were, however, of two sizes, the smaller litter about the size of large mice, which were able to escape through the meshes of the wire inclosing the cage. Now, in the hollow log where the animal in question was captured were two females; one of these escaped, doubtless deserting her own brood which were captured with the other litter and their mother.

This incident is mentioned because of statements in the literature that a female may carry two litters of different ages. It is suggested that such cases are to be explained on the theory that one litter is an adopted one. For until the young are weaned and left to lead an independent existence the mother's teats are enormously enlarged and absolutely unfit for any newly born young that might appear (compare, e. g., the teats in figs. 6, pl. 2 and 45, pl. 10). Physiologically, birth during lactation is not to be excluded; but such embryos would be doomed to perish by starvation even though they reached the pouch.

BIRTH.

We pass now to a consideration of the birth. As suggested at the opening of this article, very few observations on the birth of marsupials exist. Doctor Michel witnessed the birth in 1849; and his observations ought to have been sufficient to refute the imaginary tales of the uninitiated concerning the phenomenon. The manner in which the extremely miniature young (fig. 6, pl. 2) reached the pouch and became attached to the teats still remained obscure, although Doctor Michel did not think the mother placed the young on the nipples with her lips.

Actual observation, however, showed the process to be as simple as it is remarkable. For the young reach the pouch without the aid of the mother—these 11-day-old embryos are born into the world with sufficient neuromuscular coordination and sensory response to clamber from the vaginal orifice into the pouch, find the teat in a maze of hair and attach themselves for a two months' stay at this haven of food and shelter. The writer witnessed this migration. The young appear at the genital opening and after being licked free of liquid and embryonic envelops by the mother they climb "hand over hand" into the pouch. Because of the position of the mother during parturition the young must climb upward to reach the pouch.

In the case under observation 18 young were born. Thirteen are shown at *b* in figure 6, plate 2. To these were added 5 pouch young

5 days old from another litter; these are seen in the lower part of the figure (at *c*). At the upper margin of the figure (at *a*) is shown a section of the mammary gland at parturition. Three tiny teats may be seen; these have been drawn out to double their length by an hour's traction upon them by the thick tongue of the young. As the pouch young grows the mammary gland thickens and the teats lengthen greatly (figs. 47 and 45, pl. 10). Thus the young remains attached within the pouch for about 70 days before relinquishing its hold. And for another 30 days it moves freely about the mother clinging to her hair or (rarely) holding on to her tail with their own and entering the pouch for food or, when startled, for protection.

There is another point of interest in connection with the birth of marsupials, which was discovered by Professor Hill in the case of two Australian and one South American species. Professor Hill found that the embryos at birth do not pass out by the circuitous route through the lateral vaginal canals but are forced out by a new and purely temporary passage (the "pseudo-vaginal passage") leading from the uteri straight to the median vaginal canal. This phenomenon the writer also observed in the opossum. As Professor Hill suggests in a personal letter: "It seems probable that this passage occurs in all marsupials and is a class character."

It is thus seen that the popular notions concerning the generation of the opossum have no foundation in fact. Marsupials are indeed unique in the extremely early birth and the performance of the newly born young which is little less than marvelous; but otherwise there is no fundamental difference between the higher and the lower animals.

EXPLANATION OF PLATES.

(Those marked with an asterisk (*) were photographed in the living state; that is, immediately on removal from animal.)

PLATE 1.

* Fig. 1. Gray male and albino female of the opossum, *Didelphys virginiana*.

* Fig. 2. At home on the Red River (Photo by Dr. E. H. Sellards).

* Fig. 3. Thoroughly "p'aying 'possum," a rare occurrence.

Fig. 4. Pouch young attached to teats. $\times 1$.

PLATE 2.

* Fig. 5. Generative organs and bladder, at resting stage between two oestrous periods. The two ovaries (ov.) the two narrow uteri (ut.) connected with the broad ligament, the two lateral vaginal canals (l. v. c.) and the median vagina (vag.) are well shown. $\times 1$.

Fig. 6. Thirteen newly-born pouch young (*b*), five pouch young a week old (*c*). Above, at *a*, cross section of mammary gland showing three teats on lower edge occupied for one hour by the newly-born pouch young. $\times 1$.

* Fig. 7. The generative organs at œstrus, showing greatly swollen lateral vaginal canals (l. v. c.) and ripe follicles in ovary (ov.). Ut. uterus. $\times 2$.

PLATE 3.

* Fig. 8. Pseudopregnant organs. Retrogression of uteri has already set in $\times 1$.

* Fig. 9. The organs in pregnancy, near term. Slightly reduced.

PLATE 4.

* Fig. 10. Uterus everted, showing eight vesicles, somewhat more advanced than the egg shown in Figure 13. $\times 1$.

* Fig. 11. Open uterus No. 560', showing vesicles containing embryos with 8-10 somites; 18 hours later than egg shown in Figure 13.

* Fig. 12. 9 vesicles within a bag made of the uterine mucos. $\times 1$.

Fig. 13. One egg of batch No. 560 (cf. fig. 11). $\times 8$.

* Fig. 14. Twelve 4-celled eggs, No. 293. The white spot in center is the "yolk" or ovum proper. $\times 8$.

* Fig. 15. Sister eggs to batch 293 (fig. 14), 83½ hours later. $\times 8$.

PLATE 5.

* Fig. 16. Three normal vesicles, one abnormal vesicle and seven unfertilized eggs. No. 585. $\times 8$.

* Fig. 17. Embryos 585', five days later. $\times 1$.

* Fig. 18. Eggs No. 561. $\times 8$.

* Fig. 19. Embryos 7½ days later, No. 561'. $\times 1$.

PLATE 6.

* Fig. 20. Young vesicles No. 582. $\times 6$.

Fig. 21. Two vesicles No. 582' with embryos, 2½ days later. These are two of the vesicles shown in Figures 24 and 25. $\times 2½$.

* Fig. 22. The surviving uterus of No. 582. $\times ½$.

* Fig. 23. A similar stage with the musculature cut away leaving only the mucosa. The bulging vesicles may be seen. $\times ½$.

* Fig. 24. The uterus of No. 582 opened, showing vesicles in situ. $\times ½$.

* Fig. 25. The same. The eggs are floated out to show the depressions in the mucosa ("implantation sites") made by the vesicles. $\times ½$.

PLATE 7.

Fig. 26. Section through a 4-celled egg. Note extruded yolk about the cells. $\times 200$.

Fig. 27. 30-celled egg. The hollow vesicle is in process of formation. Yolk within the partially completed vesicle. $\times 200$.

Fig. 28. Ovum in stage of young vesicle (center) with concentric layers of albumen about it. *Sm*, shell membrane (shrunken). $\times 125$.

Fig. 29. Opossum egg showing an *Ascaris* egg (*a*) embedded in the albumen.

* Figs. 30, 31, and 32. Three double-yolked eggs at various stages of development (arrows).

PLATE 8.

- Fig. 33. 65-celled vesicle showing one large entoderm mother cell leaving its place in the wall. $\times 500$.
- *Fig. 34. Somewhat more advanced vesicles (shown in greater detail in fig. 35). $\times 8$.
- *Fig. 35. Detail of egg shown in figure 34. The thinning of the wall of vesicle is apparent. Photographed alive. $\times 82$.
- *Fig. 36. 1 mm. vesicles. A section of one of these is shown in figure 37. $\times 8$.
- Fig. 37. Section of 1 mm. vesicle showing shell membrane, remnant of albumen, ectoderm, and entoderm.

PLATE 9.

- Fig. 38. Detail of an egg, shown photographed alive in figure 41. The primitive streak is indicated by a tongue-shaped shadow. $\times 16$.
- Fig. 39. Portion of section through embryo of egg similar to that shown in figure 38. Three mesoderm cells are shown (one is marked *m*).
- Fig. 40. Portion of section through egg shown in figure 38. There are six or seven mesoderinal cells.
- *Fig. 41. Vesicles photographed alive (cf. figs. 38-40). $\times 8$.
- Fig. 42. Embryo near term, with umbilicus and shreds of embryonic envelopes.
- *Fig. 43. Photograph of primitive streak stage, taken alive.
- Fig. 44. (from Selenka) embryos in utero. The large vesicles are the allantois. (See text.)

PLATE 10.

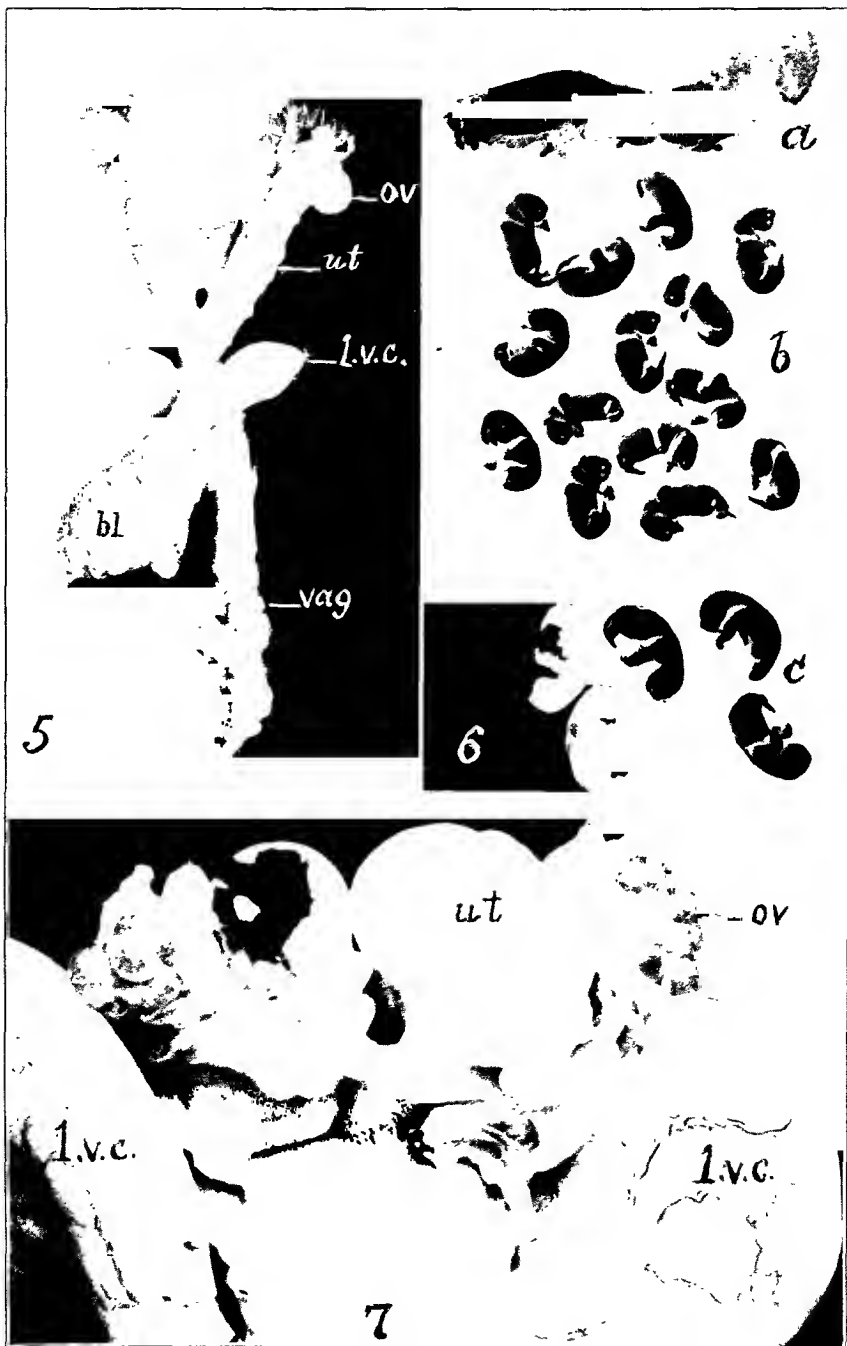
- Fig. 45. Section through four suckled mammae and two unoccupied mammae (*a*). Seen in surface view in figure 46. $\times 1$.
- *Fig. 46. View of pouch with greatly swollen mammae. Reduced.
- Fig. 47. Skin of pouch with mammae. One pouch young has been removed, one remains attached. These are about 10 days old.



1



2





(FOR EXPLANATION SEE PAGE 382)



10



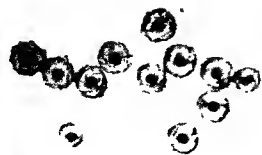
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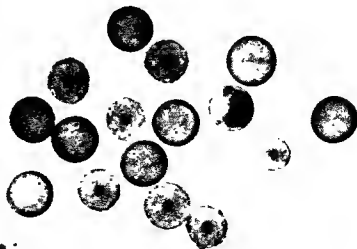
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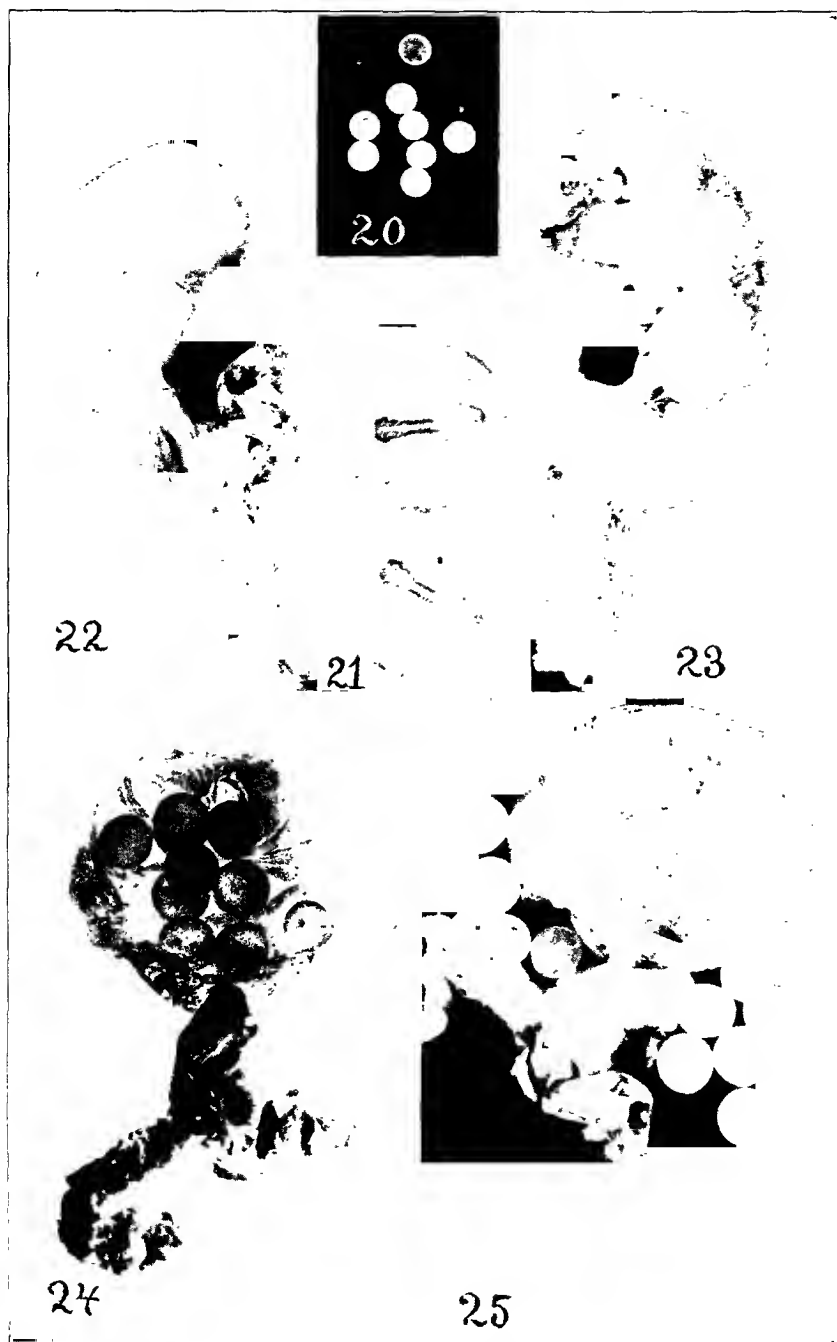


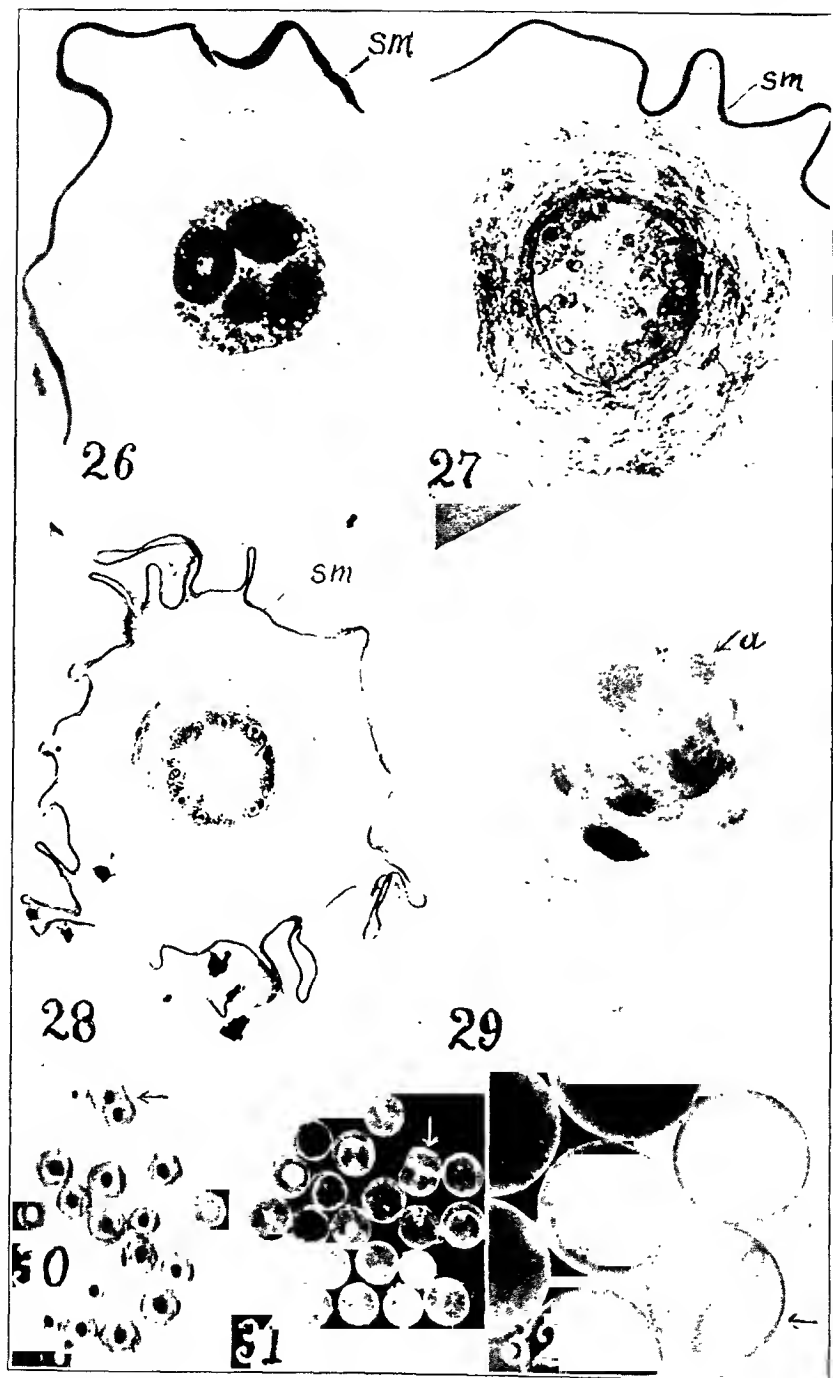
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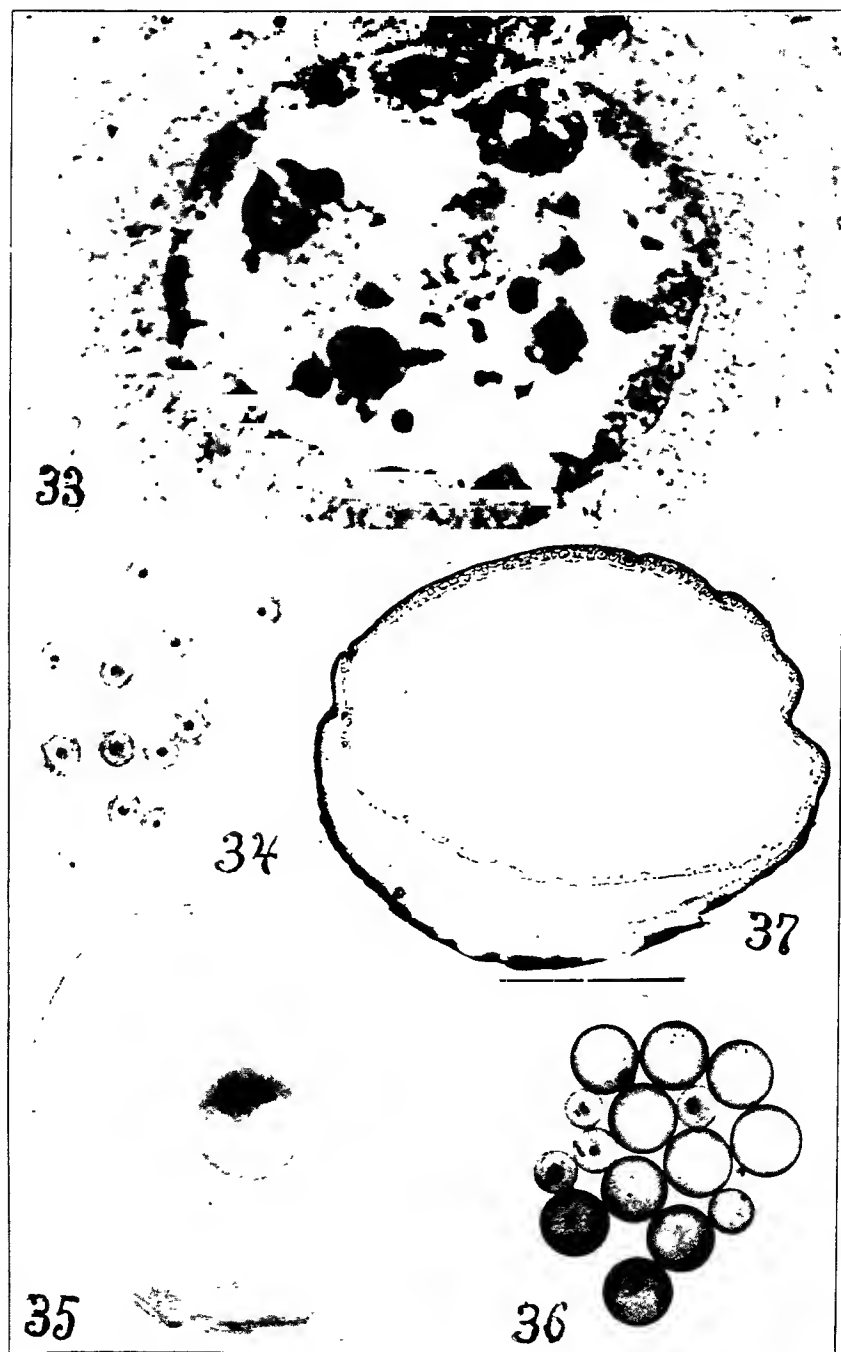


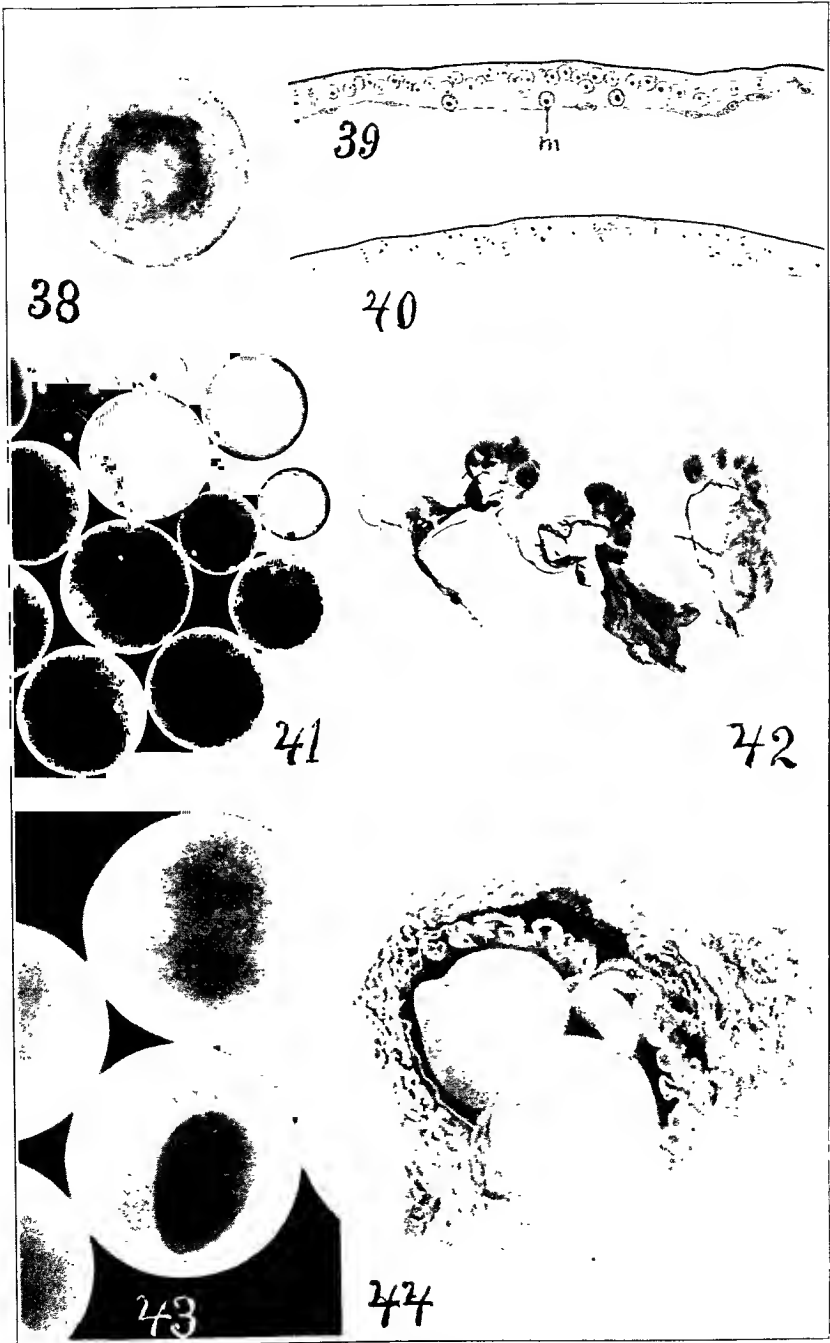
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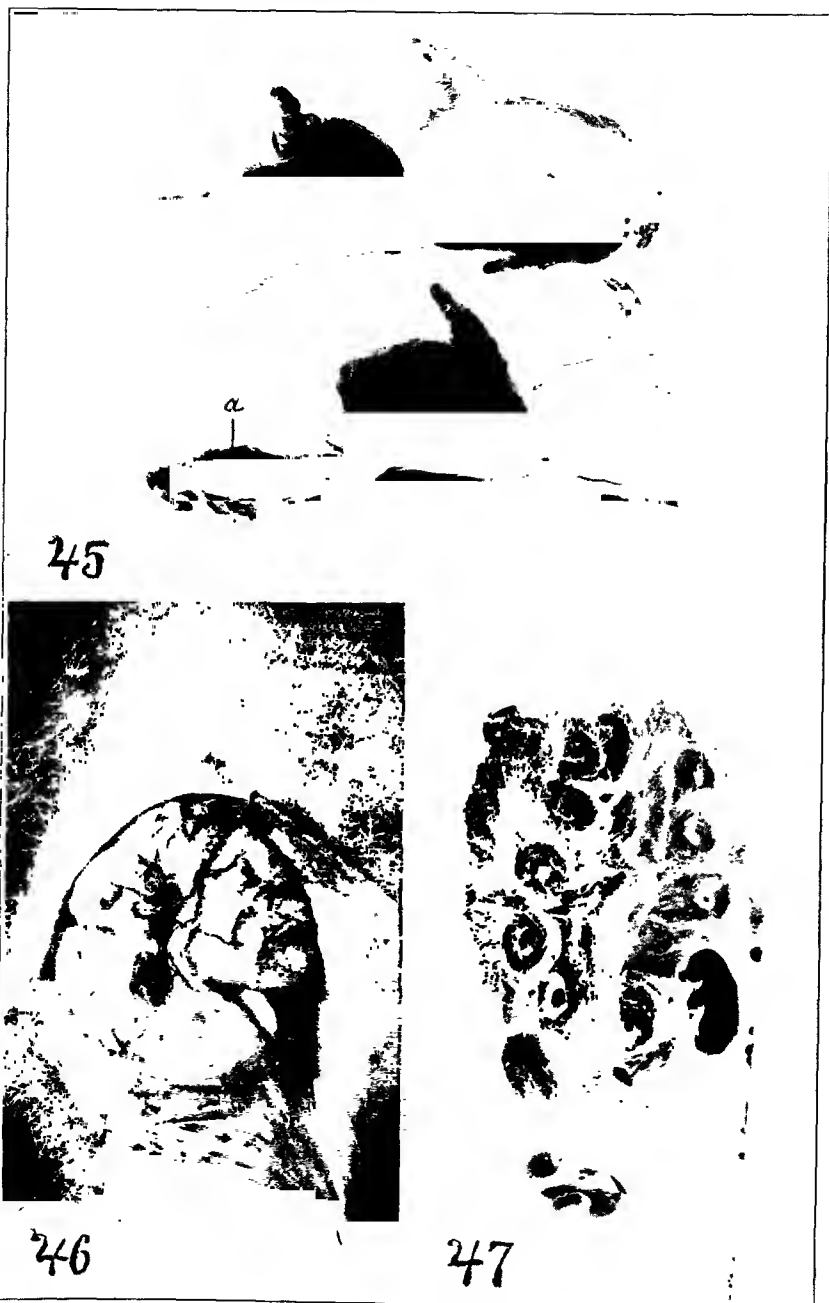












SOME PRELIMINARY REMARKS ON THE VELOCITY OF MIGRATORY FLIGHT AMONG BIRDS, WITH SPECIAL REFERENCE TO THE PALEARCTIC REGION.¹

By Col. R. MEINERTZHAGEN, D. S. O., M. B. O. U., F. Z. S.

* The question arises at once as to whether migratory flight is of a different nature from daily flight in search of food or to escape enemies. We have some interesting opinions on this subject. Gätke tells us that the speed of birds during their daily locomotions in the air has not an approximate relation to the wonderful velocity of flight attained by them during their migrations. He accounts for such enormous speed by the fact that birds migrate in the more elevated layers of the atmosphere, in which more uniform conditions prevail, and which are less subject to powerful meteorological disturbances.

Cooke ("Bird Migration"), on the other hand, thinks that migrating birds do not fly at their fastest. He believes that their migrating speed is usually from 30 to 40 miles an hour, and rarely exceeds 50. Flights of a few hours at night, alternating with rests of one or more days, make the spring advance very slow. He goes on to say that during day migration the smaller land birds seldom fly faster than 20 miles per hour, though larger birds move somewhat more rapidly.

I believe Gätke's theory to be based on faulty evidence, as I hope to show later. Moreover, birds would experience greater difficulties in flying in the "more elevated layers of the atmosphere," as the atmosphere is rarer and therefore offers a less suitable mixture on which their wings can beat. They would experience the same difficulties as a man trying to swim in froth.

My own observations tend to show that migratory flight differs very little in its velocity from the flight of daily movement, and I see no reason why it should or how it can be so. I believe migratory flight to be steady and unhurried, and that birds only fly at their fastest when pursuing or when pursued. Any one who has watched a falcon being flown at a rook will be struck by the speed which the

¹ Reprinted by permission from *The Ibis*, April, 1921, pp. 228-278.

usually leisurely flapping rook can attain from the moment he realizes he is the quarry.

I have seen rooks traveling on migration, and accurate observation gives their pace as from 38 to 40 miles per hour. Now these migratory rooks were traveling in their usual leisurely fashion, and not at anything like the speed they can use when attacked by a falcon. All other migrations which I have witnessed in many and various parts of the world confirm my belief that migratory flight differs in no way from every-day movement, except that it is steadier and possibly a trifle slower.

So in dealing with this question, I shall consider estimates of any normal flight as the normal velocity which birds attain on migration. That birds can hurry I do not doubt, but such effort could not be long sustained, and would be of little use to them in the long-distance migratory journeys they are accustomed to take.

I shall first deal with those estimates of velocity which previous writers have recorded, but which can not be regarded as reliable. Gätke claims that hooded crows fly at 108 miles per hour and blue-throats at 180 whilst on passage, and especially in the spring. He claims that bluethroats pass from between 10° and 27° of northern latitude to the fifty-fourth degree of northern latitude in 9 hours. He also assumes that the American golden plover takes but 15 hours from Labrador to northern Brazil, supporting this theory by his personal observations on godwit and curlew covering over 7,000 yards in 60 seconds, or at the rate of over 4 miles a minute!

His estimate of hooded crow flight is based on the assumption that their line of flight is from east to west over Heligoland, and that they make for the east coast of England. This apparently is not the case, for their line of autumnal flight over Heligoland is from northeast to southwest, and these are probably not the birds which arrive in such numbers on our central east coast. The bluethroat estimate is based on the assumption that birds fly direct from Egypt to Heligoland in one night, which is certainly not the case. His estimate of the flight of godwit and curlew, on which he bases his estimate of the flight of the American golden plover, is, I fear, but an example of the tremendous enthusiasm of this charming character for his subject.

But Gätke is not alone in overestimating the velocity of flight. Many other writers have erred through basing a theory on bad evidence or no evidence at all, one of the most remarkable of these being Crawford ("Round the Calendar in Portugal"), who convinced himself that turtledoves flew at such an astonishing pace that by leaving Kent at dawn they would be in Portugal a few hours later.

As regards more accurate data, it was my fortune during the recent war to have the opportunity of using anti-aircraft arrangements for my purpose. It was excellent practice for the men, and the results can be taken as accurate for all practical purposes. In conjunction with observations of an accurate nature from other sources, I have compiled the following table.

Unless the authority is stated in parentheses, the observations are my own.

The following notes refer to the table:

NOTE A.—Observations taken at Quetta by two persons with stop watches over a measured distance varying from 400 to 660 yards. All birds were below 1,000 feet, and in no case were they migrating.

NOTE B.—Observations taken in East Africa in the autumn of 1915 on migrants by using theodolites on a base of 1,200 feet.

NOTE C.—Observations made at Dar-es-Salaam by a system of two persons with stop watches stationed 440 yards apart and timing birds flying between points aligned by two stakes. All observations taken on still evenings when birds were flying to and from their breeding grounds.

NOTE D.—Observations made near Rafa, in southern Palestine, during the autumn of 1917 by means of theodolites at two anti-aircraft gun stations on a base of 3,026 feet, the stations being connected by telephone.

NOTE E.—Observations taken in southern Palestine by stop watches at 440 yards distance and timing birds flying between two points aligned by posts.

NOTE F.—Observations made near Montreuil, in northeast France, by means of theodolites on a 1,420-foot base and small balloons to ascertain the velocity of the wind at the altitude of flight. All birds believed to be on migration.

Species.	Place.	Ground speed (miles per hour).	Remarks.
Ravens.....	South Palestine....	32-39½	11 observations. Birds passing to and from roosting. Wind calm. Altitude of flight 310-840 feet. (See note D.)
Rooks.....	Northeast France.	1-45	Taken with air-speed indicator from airplane. (R. A. F.)
Do.....	.....do.....	39	Altitude of flight 1,740 feet. Wind 17 miles per hour side. (See note F.)
Do.....	.....do.....	38	Altitude of flight 2,120 feet. Side wind of 31 miles per hour. (See note F.)
Rooks and jackdaws.....	.....do.....	40	Altitude of flight 690 feet. Slight side wind on ground. (See note F.)
Rooks.....	.....do.....	39½	Altitude of flight 2,008 feet. Head wind 12 miles per hour. (See note F.)
Hooded crow.....	Rossitten.....	31.5	Average of observations on 20 birds. (Thienemann.)
Jackdaw.....	.....do.....	32.6	Average on several birds. (Thienemann.)
Chough.....	Quetta.....	11½	Very strong head wind. (See note A.)
Starling.....	.....do.....	43-49	13 observations. Wind calm. (See note A.)
Do.....	South Palestine....	45-48½	22 observations. Altitude of flight 120-325 feet. Wind calm. (See note D.)
Do.....	Rossitten.....	46.5	A single bird. (Thienemann.)
Rose-colored starling.	Quetta.....	38, 40½	2 observations. Weather calm. (See note A.)
Finches.....	Rossitten.....	33	6 observations (Thienemann.)

¹ Air speed

Species.	Place.	Ground speed (miles per hour).	Remarks
Crossbill	Rositten	37.5	Average of 2 observations. (Thienemann.)
Corn-buntins	Palestine	29½	Average of 2 observations. Birds flying to water. (See note E.)
Calandra lark	do	34	Average of 3 observations. Birds coming from water. (See note E.)
Red-throated pipit ..	East Africa	26.5	Altitude of flight 210 feet. Wind calm. (See note B.)
Do	Palestine	20½	Birds coming to water. Average of 2 observations. (See note E.)
Pipits	Tuscar Rock	20	(Patten, Zoologist.)
Wagtails	East Africa	30.1	Altitude of flight 160 feet. Slight following wind. (See note B.)
Do	do	29	Altitude of flight 210 feet. Calm. (See note B.)
Swallow	France	106	A swallow was taken from Roubaix to Paris, distance 160 miles, and returned to Roubaix 60 minutes after its liberation. (Zoologist, 1887, ex Globe.)
Do	East Africa	37½	Altitude of flight 235 feet. Wind calm. (See note B.)
Do	do	34	Flying at ground-level. Strong head wind. (See note B.)
Swifts	Mesopotamia	Over 68	Large flock at 6,000 feet, feeding over Mosul. They circled round machine and easily overtook it. Flying speed 68 miles per hour. (R. A. F.)
Roller	East Africa	38.7	Altitude of flight 720 feet. Slight head wind. (See note B.)
Lanner falcon	South Palestine ..	48	Bird not hunting. (See note D.)
Kestrel	East Africa	40½	Altitude of flight 210 feet. Weather calm. (See note B.)
Do	do	43.9	Altitude of flight 310 feet. Weather calm. (See note B.)
Do	do	22	Altitude of flight 150 feet. Strong head wind. (See note B.)
Marsh-harrier	Quetta	31, 36	Observations on two males hunting. Weather calm. (See note A.)
Do	South Palestine ..	37½	Single bird hunting. (See note E.)
Lammergeier	Quetta	79½	Gliding to food at angle of 12° to horizontal. Strong side wind. (See note A.)
Do	Italy	110	Bird nose-diving to escape from a pursuing airplane. Observation taken with air-speed indicator. (R. A. F.)
White Stork	Mesopotamia	148	Birds on spring passage at 4,200 feet over Bagdad. Birds drew in their necks and legs when machine was near. (R. A. F.)
Grey heron	France	Under 145	By air-speed indicator. (R. A. F.)
Gannets	Eastbourne	148	Do.
Pelican	South Palestine ..	51	Altitude of flight, 1,240 feet. A side wind of 15 miles per hour. (See note D.)
Geese	(?)	41.3	Altitude of flight, 905 feet. Measured by theodolite (Clayton, Science, n. s., vol. v., No. 105.)
Do	France	155	By air-speed indicator. (R. A. F.)
Geese and duck	Mesopotamia	42-48	Frequent observation by air-speed indicator
		Slightly faster.	Birds usually on passage, but all below 3,000 feet. (R. A. F.)

¹ Air speed

Species.	Place.	Ground speed (miles per hour).	Remarks.
Geese.....	France.....	50½	Altitude of flight, 4,210 feet. Head wind of 9 miles per hour. (See note F.)
Duck.....	(?).....	47.8	Altitude of flight, 958 feet. Measured by a special theodolite. (Clayton, <i>ibid.</i>)
Do.....	Quetta.....	51-59	Eleven observations. Wind calm. (See Note A.)
Brent geese.....	Scotland.....	1 45	By air-speed indicator. (Wynne.)
Mallard.....	(?).....	1 50	By air-speed indicator. Birds believed to be on passage. (Wynne.)
Do.....	France.....	Under 1 50	By air-speed indicator. (R. A. F.)
Teal.....	South Palestine...	44	Single bird flying low and leisurely. (See note E.)
Houbara bustard...	Quetta.....	42½	A single bird. Wind calm. (See note A.)
Stock dove.....	do.....	42½	Fairly strong head wind. Bird flying to water. (See note E.)
Turtle dove.....	Sinai.....	37	Several tests made on birds flying their best alongside a train. Speed of train obtained from kilometer posts. No record of wind.
Sand-grouse (<i>Pt orientalis</i>).	Quetta.....	43½	Bird flying from water. Slight head wind. (See note A.)
Sand-grouse (<i>Pt senegallus</i>).	South Palestine...	47½	Bird flying from water. Altitude of flight, 460 feet. Weather calm. (See note D.)
Pheasant.....	.....	33.8	Experiment in covered gallery. (Field, Feb., 1887.)
Do.....	.....	38.1	Experiment in the open. (Field, Feb., 1887.)
Partridge.....	.....	32.1	Do.
Do.....	.....	1 40	By air-speed indicator. (R. A. F.)
Quail.....	Mediterranean...	57	Timed at sea over 500 yards distance. Birds on passage. (Lynes, Brit. B., vol iii.)
Geoffroy's plover (<i>Ch. geoffroyi</i>).	Palestine.....	34	Timed by speedometer in the Bay of Acre, birds flying directly in front of the car. Birds could be pressed up to 39 miles per hour, after which the car could overtake them. Wind calm.
Kentish plover.....	do.....	34	Same as for Geoffroy's plover.
Caspian plover (<i>Ch. asiaticus</i>).	East Africa.....	31	Birds flying very low on passage. Wind calm (See note B.)
Caspian plover.....	do.....	47	Birds flying at 450 feet. Strong side wind. Birds on passage. (See note B.)
Dotterel.....	South Palestine...	45, 50½	Two observations. Birds flying very low. Strong side wind of 11 and 21 miles per hour, respectively. (See note D.)
Golden plover.....	England.....	1 60	Birds being pressed. By air-speed indicator (Wynne.)
Pacific plover (<i>Ch dominicus</i>).	.....	50-75	Not founded apparently on accurate observation. (Henshaw, Smithsonian. Inst. Rep. 1910.)
Lapwing.....	S. Palestine.....	37	Single bird, flying against head wind of 12 miles per hour. Altitude of flight 500 feet. (See note D.)
Do.....	France.....	50	Altitude of flight 5,500 feet. Flying against a north wind on spring passage. Means of estimate unknown. (Portal, Field, 17. in. 17.)
Do.....	do.....	1 10 15	Observation by air-speed indicator. (R. A. F.)
Do.....	do.....	42	Altitude of flight 1,110 feet. Slight side wind at ground level. (See note F.)

1 Air speed.

Species.	Place.	Ground Speed (miles per hour).	Remarks.
Little stint.....	East Africa.....	49	One observation. (See note C.)
Terek sandpiper.....	do.....	48-51	Four observations. (See note C.)
Greenshank.....	do.....	46, 49	Two observations. (See note C.)
Marsh sandpiper.....	do.....	48, 51, 51½	Three observations. (See note C.)
Oystercatcher.....	do.....	45-49	Seven observations. (See note C.)
Curlew.....	do.....	42-48½	Seventeen observations. (See note C.)
Whimbrel.....	do.....	43-52	Nine observations. (See note C.)

So much for observations on the flight of wild birds. I shall now briefly record some of the more accurate observations on the rate of flight of carrier pigeons.

Tegetmeier declares (Field, 22, i, 87) that the average speed of carrier pigeons is 36 miles per hour, whilst on two occasions a speed of 55 miles per hour was maintained for four hours in succession.

From experiments carried out in a covered gallery (Field, 1887, p. 242) it was shown that a pigeon flew at 33.8 miles per hour, whilst in the open another flew at 27.9 miles per hour.

In the Homing Fancier's Annual of 1892 it was recorded that in covering 82 miles in good weather a bird maintained just over 71 miles per hour. From the Scilly Islands to Wiltshire (215 miles) a bird kept up a speed of 50½ miles per hour. In 170 miles a bird made 54 miles per hour, and in 104 miles it made 57½ miles per hour. In a race from Banff to Hampshire a bird maintained 62 miles per hour in very favorable weather. Finally, a celebrated bird called "Volonel" on two occasions maintained over 60 miles per hour.

Doubtless other figures have been published, but I have been unable to trace them. From the data available it appears that the normal velocity of a carrier pigeon is from 30-36 miles per hour, but that when "homing" they can attain up to 60 miles per hour or over. Again arises the question as to whether migrants can accelerate their speed when actually migrating, in the same manner that a "homing" pigeon can hurry on its way when "homing." For reasons already given, I do not think they do, and there is certainly no evidence which even suggests it. The cases of rooks in the above table were certainly those of migrating birds, and indicate no hurry. The Rossitten birds were all on passage, and show no excessive speed. In fact, the only excessive speeds we have in the table are those of the two Lammergeier which were taken under abnormal conditions, the golden plovers which were escaping pursuit, and the Roubaix swallow. It is remarkable that this bird was also "homing," which may account for such an abnormal speed.

But swallows are most deceptive birds as regards their flight. They are in reality neither strong nor rapid fliers, and personally I do not attach too much reliance in the data of the Roubaix swallow. I do not believe any swallow is capable of anything approaching that speed unless assisted by a tail wind of 30 or 40 miles an hour, which, as is well known, is a hateful condition to a traveling bird.

The case of the Mosul swifts is interesting. The birds were probably not on passage, but simply feeding. It is known that swifts travel great distances in search of food and ascend great altitudes. In the Middle Atlas of Morocco, in the Himalayas, in Crete and Palestine, 4,000 or 5,000 feet and 50 miles or so in distance seems nothing to these incomparable fliers. I have had splendid opportunities of observing both the Alpine, common, and spine-tailed (*Chaetura*) swifts, and it has been a great disappointment to me that I have never been able to get a satisfactory estimate of their rate of flight, as they never continue on an even course. On a small island off the coast of Crete, I was recently given a good exhibition of what an Alpine swift can do. I was watching some of these birds feeding round cliffs in which several pairs of Eleonora's falcon were about to breed. Now, this delightful falcon is no mean flier, and as these swifts passed their cliff, the falcons would come out against them like rockets. The swifts would accelerate, and seemed to be out of sight before the falcons were well on their way. So confident were the swifts in their superior speed, that every time they circled round the island they never failed to "draw" the falcons, and seemed to be playing with them. I may add that these same falcons have little difficulty in overhauling and striking a rock pigeon—itself no mean performer. I have also seen on record the case of falcons and swifts somewhere in India, when the former failed time after time to come up with his quarry. I unfortunately can not trace the reference.

I hesitate to even guess at the speed to which a swift can attain when the necessity arises, but the main point is that this, the fastest of birds, can increase his "feeding" speed of, say, 70 miles per hour to a velocity which must exceed 100 miles per hour. There is little doubt that the speed of the golden plover in the table is an accelerated speed. Pilots in Mesopotamia have told me that whereas geese can not to any great extent accelerate, duck, when pressed, could attain a speed of about 60 miles per hour.

To conclude, I find that birds have two speeds—a normal rate which is used for every-day purposes and also for migration, and an accelerated speed which is used for protection or pursuit, and which in some cases nearly doubles the rate of their normal speed. Some of the heavier birds can probably only accelerate to a slight

extent. In this conclusion I am naturally excepting "courtship" flight, which is usually of an accelerated nature.

I also find, after eliminating abnormal conditions and observations based on meager evidence, that the normal and migratory rate of flight in miles per hour is as follows:—

Corvidæ-----	31-45	Starlings-----	38-49
Smaller passeræ-----	20-37	Falcons-----	40-48
Geese-----	42-55	Ducks-----	44-59
Tame pigeons-----	30-36	Sandgrouse-----	43-47

Waders 34-51, but mostly from 40-51.

A BOTANICAL RECONNAISSANCE IN SOUTHEASTERN ASIA.

By A. S. HITCHCOCK.

[With 11 plates.]

The following sketch of the region is based upon a visit made in 1921 to the Philippines, Japan, China, and Indo-China for the purpose of studying and collecting grasses for the United States Department of Agriculture.

The itinerary was as follows, the localities referring to places where collections were made:

Philippines: Vicinity of Manila, Los Baños, Baguio.

Japan: Yokohama, Tokio, Lake Hakone, Mt. Fuji, Nikko and Lake Chuzenji, Kyoto, Nagasaki.

China: Shanghai, Nanking, Kuling, Hongkong, Canton, Yingtak, Shichow, Whampoa, Lohfau, Macao, Pakhoi, island of Hainan.

Indo-China: Haiphong, Hanoi, Vinh, Hue, Tourane.

PHILIPPINES.

These islands have been so well exploited biologically by the Bureau of Science that only time enough was spent here to obtain a general view of the grass flora. The native vegetation has been largely replaced in the vicinity of Manila by introduced species, so that most of the grasses here belong to the category of weeds.

The grass supply for horses and other animals in Manila is furnished partly by roadside species but largely by *Homalocenchrus herandrus*. This species is found in wet soil in the tropics of both hemispheres, but it was surprising to find it cultivated for forage. Large fields in the vicinity of Manila are devoted to this grass, the plants being set out from divisions of the tufts, and treated much in the same manner as rice. The grass is cut, tied in bundles, and transported green to the city. The usual name applied to it is zacate, the Spanish name for grass.

One of the commonest grasses is cogon (*Imperata cylindrica*), which is found also in tropical Asia. It is an aggressive species.

tending to intrude in all open places and sometimes occupies enormous areas, called cogonales by the Filipinos. Cogon is often used as a thatch for the roofs of houses and sheds.

At Los Baños, the seat of the agricultural college, one has an opportunity to explore virgin forest on Mount Maquiling. On this mountain is preserved, at a point easily accessible from Manila, the undisturbed native vegetation. In ascending this mountain the writer had his first experience with one of the worst pests of the Old World Tropics—the leeches. These are brownish worms as much as an inch long and one-eighth inch in diameter. They are present in countless numbers on the fallen leaves on the floor of the trail and on the vegetation along the sides. As one walks along the leeches are seen to advance like measuring worms, now and then waving a free end in the air, attaching themselves with wonderful dexterity to any part of the body with which they come in contact. The feet may be protected by wearing shoes in which the tongue is sewed to the body along each side to the top and then wrapping the legs closely with wool puttees, being careful to come down well over the top of the shoe. Thick socks drawn up outside the legs of the trousers may take the place of puttees. Soap well worked into the socks is a deterrent. Particular care must be taken to prevent their entrance to the nose, eyes, and other openings in the body. They are usually able to attach themselves without exciting the sense of touch. Persons going in pairs watch each other for attacks about the head and neck. When they find lodgment they gorge themselves with blood and become oval in shape and finally fall off, but they inject a substance which prevents the coagulation of the blood and a wound bleeds for several hours. Fortunately the leeches are troublesome only in very wet woods during or between showers. On Mount Maquiling they did not extend as low as Los Baños.

A trip was made to Baguio, a resort in the mountains about 170 miles north of Manila at an altitude of nearly 5,000 feet. The weather here is cool and comfortable in summer, in striking contrast to that of Manila at this season. The trail to Santo Thomas (about 7,000 feet) led through grassy mountain slopes and yielded an excellent collection of grasses.

JAPAN.

Japan is very mountainous and largely forested, hence not pre-eminently a grass country. Aside from bamboos, only about 50 species were collected here while in some localities in China as many species might be obtained in a single day. Even in the grassy slopes and meadows in the vicinity of Lake Hakone, though the individuals were numerous the species were few. Mount Fuji is a beautiful

mountain as viewed from a distance, its nearly perfect cone dominating the view like our Shasta and Rainier, but botanically it is disappointing, especially from the agrostological standpoint. As observed on the ascent from Gotemba, there is an abrupt transition from timber line to the bare cinder slopes above. There are no alpine meadows harboring interesting grasses, as are found on most mountains, the portion above timber line here being devoid of vegetation. An account of the vegetation is given by Hayata.¹ Fujiyama or Mount Fuji is a beautifully symmetrical somewhat truncated cone, 45 by 30 kilometers wide at base and 3,778 meters altitude, the upper slopes being about 34°. Hayata states that in the *Salix-Alnus* region, about 2,500 meters, there are three species of grasses (*Agrostis canina*, *Glyceria tonglensis*, *Miscanthus matsumurae*), and that "above the *Salix-Alnus* formation, there comes a small area of higher (alpine) grass formation. This formation is, however, very poor on this mountain, owing to its recent habitation. Only 29 species are listed for this region on the whole mountain, and only one of these (*Deschampsia caryophyllea*) is a grass."

The bamboos are well represented in Japan both by species and individuals. The bamboo covered hills in the region of Lake Hakone were a surprising sight. Large areas, square miles in extent, were covered by a single species (*Arundinaria chino*), forming an impenetrable thicket 4 to 8 feet high.

CHINA.

China was entered at Shanghai, a city giving much evidence of foreign influence, as reflected in the fine modern buildings, electric tramways, electric lights, and many good roads. Here is located the only United States post office to be found outside of the United States or its possessions. One can mail official packages home from here under frank. Shanghai is not on the coast but about 18 miles up the Whangpo River from the seaport Woosung.

The journey of about 200 miles to Nanking was made by rail in fairly comfortable coaches. Nanking is a treaty port and was formerly the old classical capital of south China.

Ports as used in this sense are not confined to the vicinity of the seacoast but may be in connection with interior cities that have been opened to trade by treaty. Most Chinese cities are surrounded by walls, these having been for protection against invasion in earlier days. The wall of Nanking is 32 miles long and 30 to 50 feet high. A comparatively small proportion of the area within the wall is occupied by buildings, the remainder being farm land or unused grassland. The University of Nanking, a thriving missionary insti-

¹ The Vegetation of Mt. Fuji. Tokyo, 1911.

tution, is located here and has in connection with it a farm for experimental purposes.

A journey was made up the Yangtse River to Kuling, going by steamer to Kiukiang and by chair up the mountain. Kuling is a pleasant resort, at an altitude of about 3,500 feet, much frequented during the hot season by the missionaries of central China. Much of the trail is up over stone steps like a gigantic stairway and all the supplies of whatever character are brought up to Kuling by man power—coolies carrying loads balanced on each end of a single bamboo pole or a heavier load slung from a pole carried by two. For the ascent the chairs are manned by four carriers with an extra pair for relieving.

South China is entered at Hongkong, an island 30 square miles in area, under British control. The British also control the adjacent mainland to the north including the city of Kowloon and the New Territory. Between is a fine harbor buzzing with the world's commerce. Hongkong is a mountainous island, the highest point being 1,800 feet. It is a modern city with electric tramcars, a cable line to the peak, and fine buildings. The journey of 90 miles to Canton may be made by rail, or more comfortably by river steamers leaving Hongkong in the evening and arriving at Canton the next morning.

Canton is a large, thoroughly Chinese city of over 1,000,000 inhabitants. Recently broad avenues have been cut through the city in various directions giving it a more modern appearance, but one can step easily from these avenues to the narrow, crowded streets scarcely wide enough for a chair to go. Innumerable sampans flit to and fro on the river, and it is estimated that 250,000 people have their permanent residence in these sampans.

The Canton Christian College is located across the river from Canton on the island of Honam. This institution is developing rapidly and is destined to be the educational center of south China.

With the college as headquarters, excursions were made to White Cloud, a small mountain east of Canton; to Whampoa, 10 miles east of Canton, where the Wilkes Expedition made collections; and to Macao, a Portuguese colony, 40 miles southwest of Hongkong, and the first European settlement in China. A longer trip was made up the North River to Yingtak and Shiuchow, the latter at the end of the railway and about 140 miles from Canton. A four days' trip to the mountain of Lohfau was very profitable. To reach Lohfau one goes by rail from Canton to Sheklung and on foot with carriers north about 25 miles to a monastery which affords shelter for the sojourn.

In company with Mr. F. A. McClure, of the Canton Christian College, a trip was made to Indo-China and the island of Hainan, Pakhoi in southern Kwangtung being visited on the way. Hainan

is a large island off the south coast of China, about 180 miles long. Landing at Hoihow we went inland to Kachek, one day's journey by boat and two days on foot (though one can go by chair). From Kachek a boat trip was made up the river into the foothills of the central mountains.

The writer is under great obligation to the presidents and faculties of the two institutions mentioned, the University of Nanking and the Canton Christian College, and to the missionaries at Yingtak, Shiuchow, and on the island of Hainan. The cooperation of the missionaries is almost indispensable to scientists traveling in the remote parts of China.

INDO-CHINA.

Landing at Haiphong in Tongking we went by rail to Hanoi and, the next day, south by rail to Vinh. From this place over a good road the journey is by auto and is scheduled to be a day's ride to Dongha where another railway brings one to Hue, our objective. Because of excessive rains it took two days to reach our destination, the night being spent in a native hut on a Chinese bed—a board platform.

Hue, the capital of Annam, was of interest because here resided the Portuguese botanist, Loureiro, who wrote a book on the flora of Cochin China, published in 1790. It was hoped that collections made at Hue might aid in interpreting Loureiro's meager descriptions. The director of the botanic garden assigned an assistant to help us in correlating the common or Annamese names with the Latin names of the plants, and these common names were in turn checked with those given by Loureiro. The native names of conspicuous or well-known plants are probably the same now as in Loureiro's time and in several cases among the grasses the names served to confirm the descriptions. Aside from the comparison of the native names, the collections of the grasses from this region aid by showing what species Loureiro probably had at hand for study. The work of Loureiro is of importance because, being published so early, his names, when identified, have priority in many cases.

After having finished our work at Hue we visited Tourane on the coast and then returned to Haiphong the way we came.

NOTES ON BOTANY AND AGRICULTURE OF CHINA.

The conditions for collecting grasses were very favorable and a large series of specimens was obtained. One of the prime objects of the visit to China was the study of the bamboos. This group of grasses is of much importance here because of the great variety of uses to which the plants are put. The larger sorts are used for structural purposes; thin-walled sorts are split into narrow strips

to be used for baskets and ropes; certain species furnish food, the tender young shoots being used as a vegetable.

Bamboos are difficult to study and identify from herbarium specimens because most of the species flower only at rare intervals and the leaves furnish few distinguishing characters. But when the species are examined as they are growing their distinctions are more evident. One soon recognizes the different kinds by the habit of growth, the size, shape, and color of the stems, and by the appearance of the young shoots, which usually grow to the full height of the plant before sending out branches, and which are covered with large characteristic scales or bladeless sheaths. It is therefore almost necessary, in the study of this group, to supplement herbarium work by observations upon the growing plants.

Aside from the bamboos the grasses of China furnish an interesting field for study. From books and herbarium specimens one may learn much regarding the identity of the species of foreign countries but may be unable to obtain information concerning the habit of growth, the habitat or conditions under which the plants grow, and especially does one fail to form a mental picture of the grasslands or gain a knowledge as to what species are dominant in a given region. Much information of this sort was gathered throughout the trip. It is interesting to find new species but much more interesting to determine the identity of obscure and doubtful species described by early authors. The Wilkes Exploring Expedition visited Whampoa and made collections there. This place is about 10 miles below Canton on the Pearl River and was in the early part of the last century the anchorage for vessels trading with Canton. Since some of the grasses collected at that time by the Wilkes Expedition have remained obscure, a visit was made to Whampoa (pronounced Wampō). From personal observations on the physiographic features and from a study of the collection of grasses obtained it becomes comparatively easy to interpret the grasses of the Wilkes Expedition. This is only one example of many similar instances.

China is said to be a thickly populated country, and indeed the cities and villages are very much crowded. The country population is fairly dense in the valleys, which are intensively cultivated. But one is greatly surprised at the vast stretches of unused grassland, mile upon mile, on the rolling hills, uninhabited and ungrazed, covered with a luxuriant growth of nutritious grasses. This condition obtains not merely in the remote parts of the country but within sight of large cities. There are many reasons for this, but one of the most important is probably the prevalence of actual or potential banditry. A herd of cattle on these grass hills would at once invite the attack of robbers, and the rich man, the only one who could afford herds, will not risk his capital. The small farmer of the valleys, with

his small plot of ground worked by himself and family, can not utilize this open country, and farms, so far as observed in the parts of China visited, are confined to the valleys.

The industry and efficiency of the small farmer is remarkable. The land is cultivated intensively almost to the last square foot. It is an impressive sight to see the rice, field after field for miles, with a perfect stand of even growth, a maximum yield, every stalk of which has been set out by hand and will be harvested by hand. Nothing approaching such perfection can be seen in our great wheat-growing regions. We lead the world in the amount of product per man but China is far ahead of us in the product per unit of land.

At the time of the visit to the Yangtse Valley in August the river was in flood and many of the rice fields were inundated. The rice was being harvested, nevertheless, but with difficulty. Men and women were wading in the water to their waists or to their armpits, cutting the rice, much of which was submerged, tying it in bundles and placing the bundles in boats. Later the bundles were supported on the tops of poles, three or four crossed and supported like the frame of a wigwam, the whole standing in shallow water or upon the dikes between the fields. Such things as this show the relative value of food and labor.

The methods for raising water used in irrigating the fields are of interest though no special study was made of these. A simple method is by a bucket worked by two men. The bucket is supported at the middle of a rope the ends of which are held by the two men standing, say, 10 feet apart. The bucket is swung to dip in the canal at the lower level and by a dexterous swing and a single continuous motion is brought up to the higher level, a foot or two above and emptied. The rhythmic continuous motion of dipping and emptying is beautiful to look upon. There is also in common use a simple machine on the plan of a chain pump. A series of floats, a box about 6 or 8 feet long through which the lower line of floats carries the water, two sprocket wheels carrying the chain of floats, the upper of which is attached to a horizontal axle furnishing the power, these are the chief points of the machine. The horizontal axle has 3 or 4 series of projections serving for foot rests upon each of which series stands a man or woman. Holding to a suitable support the men turn these foot rests by climbing upon them in a treadmill fashion. In the Yangtse Valley similar machines were operated by water buffaloes or carabaos turning a horizontal geared wheel. One could see here scattered thickly over the landscape the little sheds under each of which was a carabao patiently walking round and round.

In the parts of China visited, the forests have long since been cut away and only in the vicinity of the monasteries does one find any considerable growth of trees. The poorer classes, especially in the villages, depend upon grass for fuel. The peasants cut the grass, weeds, and other waste vegetation, dry it in the sun, and store it in bundles for winter use. The grass is used for cooking rather than for heating and the stoves and cooking utensils are adapted to this purpose. To keep warm in winter more clothes are worn. In the cities charcoal brought from a distance is much used for cooking.

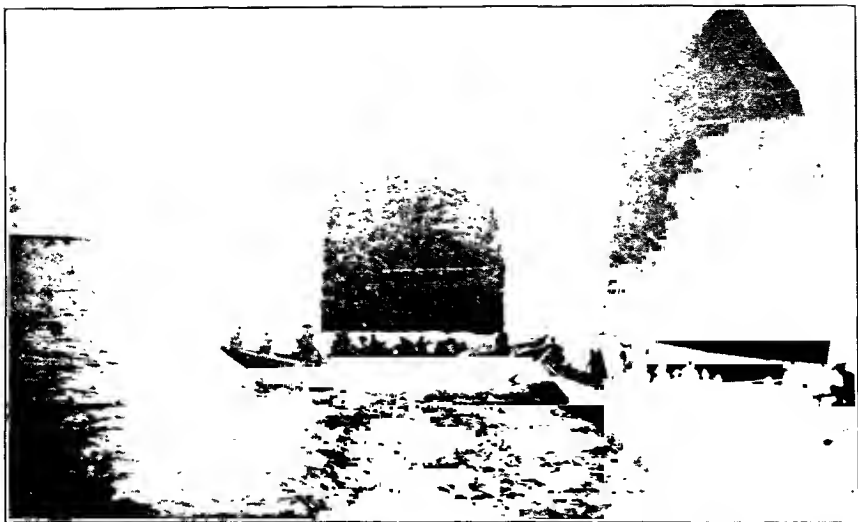
The small farms usually have upon them a small pond in which fish are kept and along which are often grown water plants, such as the lotus whose seeds and fleshy rhizomes are used for food. Every few years the mud is scraped from the bottom of the pond and used as a fertilizer. There is a compost heap upon which refuse is thrown and ultimately utilized for the same purpose. Rushes are grown for making ropes, the entire cured stems being used and twisted into strands and these into a rope. The single stems take the place of strings for tying packages.

The visitor to China observes scattered over the landscape numerous mounds and is surprised to learn that these are graves. As these graves are not to be disturbed by plowing no inconsiderable quantity of arable land is subtracted from that which might be cultivated.

Bamboo sprouts as a vegetable have already been mentioned. Another grass (*Zizania latifolia*) furnishes a vegetable of fine flavor. This is a perennial and the thickened base of the stem is sold in the markets under the name kau sun. The species is a close relative of our wild rice or Indian rice (*Zizania palustris*), which differs in being annual and has no thickened base.

A grass collected in the valley lands around Canton and between Sheklung and Lohfau Mountain is of interest inasmuch as it appears to be the wild prototype of the cultivated rice. The plants were collected along the margins of ponds, ditches, and streams. They differ from the cultivated rice in being decumbent and rooting at the base and in the narrower panicles of awned reddish spikelets.

Concerning agriculture in general one is impressed with the industry of the people, the intensiveness of the cultivation, and the high state of efficiency within the limits of the empirical methods. On the other hand one sees the great opportunity for the application of modern scientific methods by which the quality and the quantity of the products should be greatly increased.



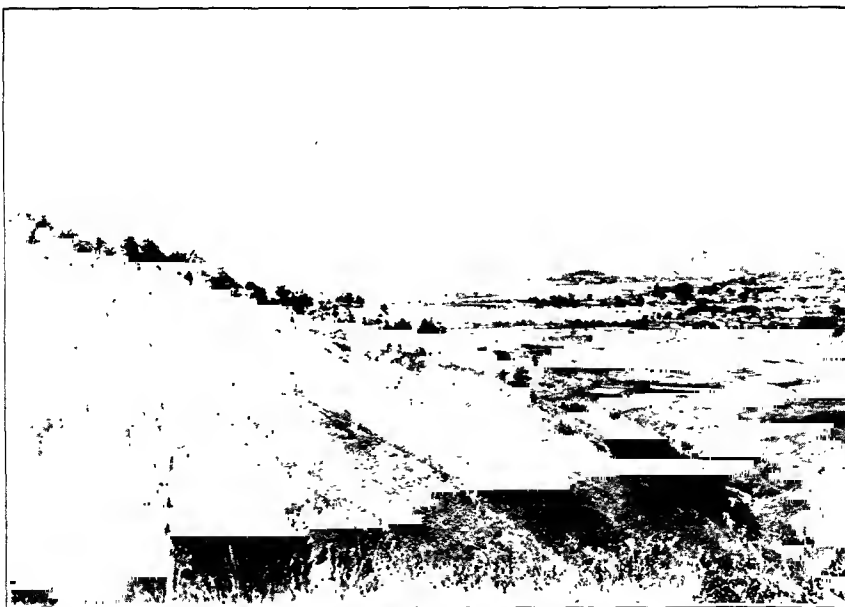
1. FISHING BOATS NEAR HOIHOW, ISLAND OF HAINAN.



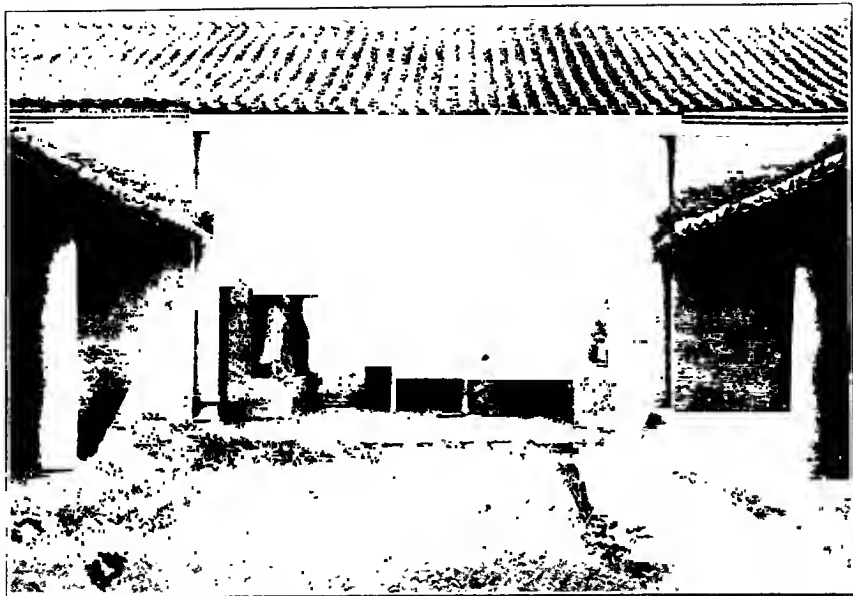
2. A STREET IN SHANGHAI, SHOWING A HEAVY LOAD TRANSPORTED ON A CART BY MAN POWER. FIVE MEN ARE PULLING IN FRONT AND ONE IS GUIDING IN THE REAR. MOST OF THE HEAVY HAULING IS DONE IN THIS WAY.



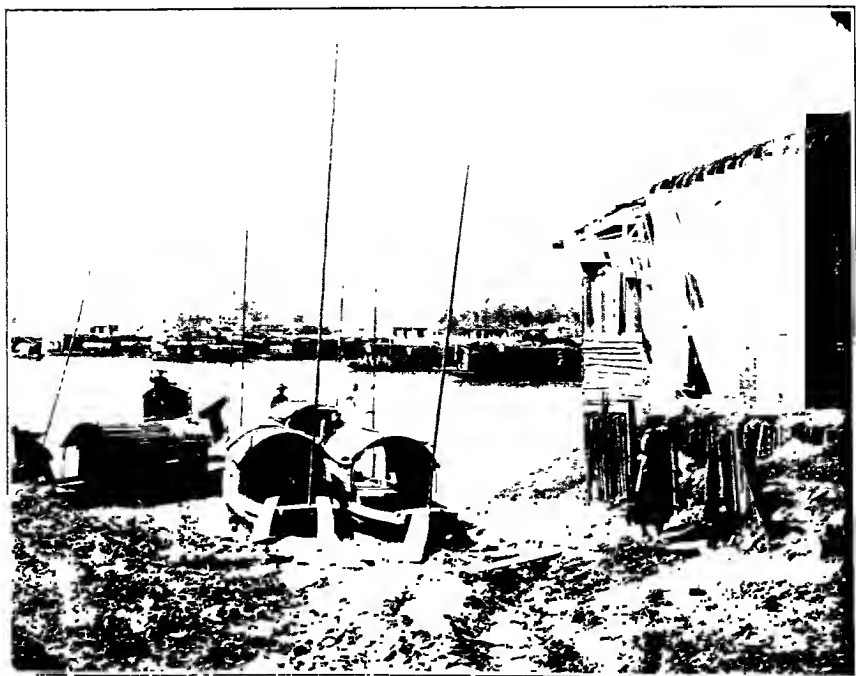
1. THE MISSION COMPOUND AT HOIHOW, ISLAND OF HAINAN. A TIDAL FLAT AT LEFT, FULL OF WATER AT HIGH TIDE. A THICKET OF PANDANUS OR SCREW PINE IN THE MIDDLE DISTANCE, A COMMON SEASHORE PLANT IN THIS REGION.



2. SHIUCHOW, CHINA, 140 MILES NORTH OF CANTON ON THE NORTH RIVER. AN ATTEMPT HAS BEEN MADE TO AFFOREST THE HILLS WITH PINES.



1. INTERIOR OF A TEMPLE AT YINGTAK, CHINA.



2. SAMPANS ALONG THE RIVER AT YINGTAK ON THE NORTH RIVER, 80 MILES ABOVE CANTON. THE BAMBOO POLES ARE USED TO PUSH THE BOAT THROUGH THE WATER.



1. NUMEROUS GRAVES IN A FIELD IN THE YANGSTE VALLEY. IN FOREGROUND ARE MULBERRY BUSHES USED AS FOOD FOR SILKWORMS.



2. A VALLEY SCENE IN THE CITY OF NANKING. THE VALLEYS ARE INTENSIVELY CULTIVATED WHILE THE HILLS ARE GRASS COVERED.



1. *ZIZANIA LATIFOLIA* AT NANKING, CHINA. THE THICKENED BASE OF THE STEMS IS USED AS A VEGETABLE CALLED KAU SUN. THE CITY WALL IS IN THE BACKGROUND DISPLAYING ADVERTISEMENTS.



2. A SMALL FARM AT NANKING. TARO IN THE FOREGROUND: THE FLESHY ROOTS USED FOR FOOD. THE ADOBE HUT IS THATCHED WITH GRASS BUNDLES OF GRASS FOR FUEL ARE STORED IN THE STACK.



1. A COMMON TYPE OF BAMBOO HOUSE. THE ROOF THATCHED WITH PALM LEAVES. LUZON, PHILIPPINE ISLANDS.

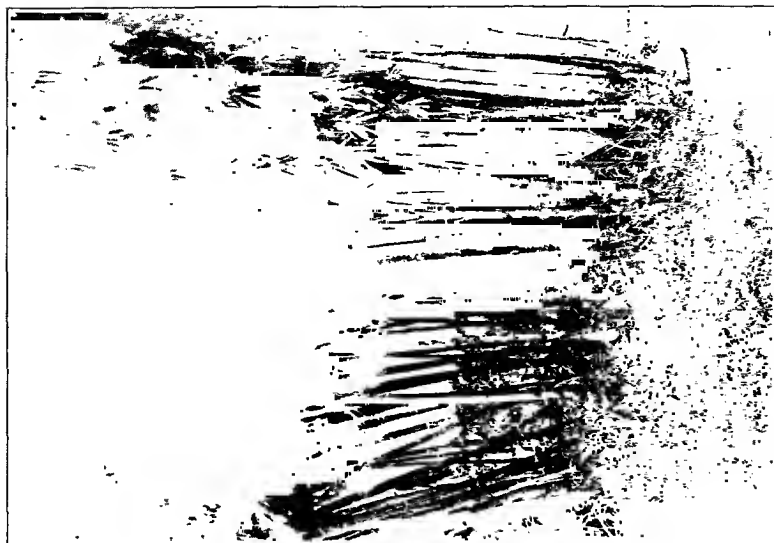


2. NATIVES CUTTING GRASS (*HOMALOCENCHRUS HEXANDRUS*) NEAR MANILA. THIS NATIVE GRASS IS CULTIVATED AS FORAGE FOR HORSES.

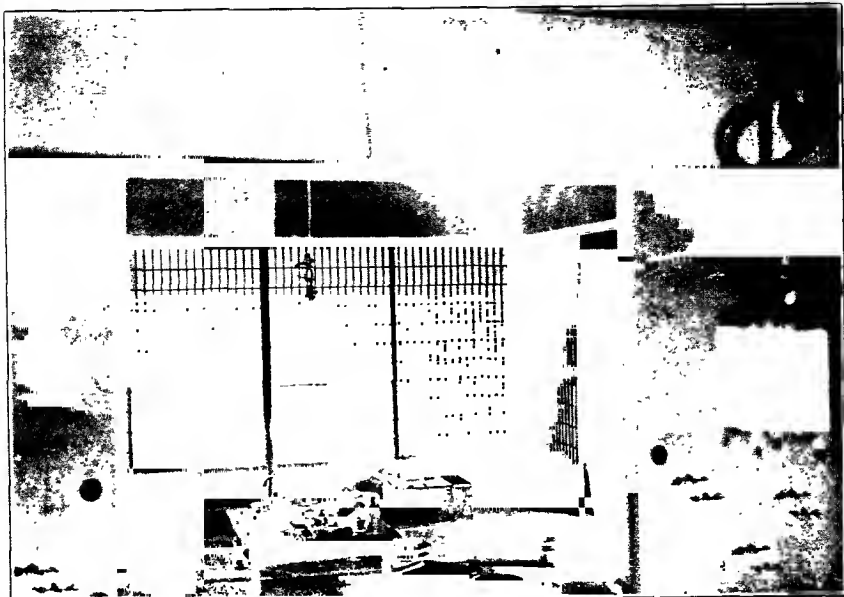
(Photograph furnished by the Bureau of Science.)



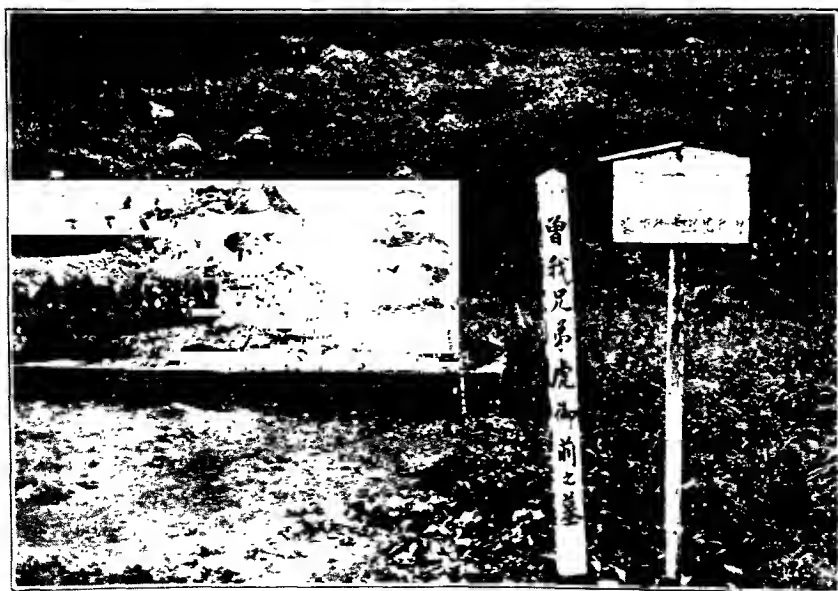
1. THE EDIBLE BAMBOO (*BAMBUS BEECHEYANA*) CULTIVATED NEAR CANTON. THE YOUNG SHOOTS, AS THEY ARE EMERGING FROM THE SOIL, ARE CUT AND USED AS A VEGETABLE.



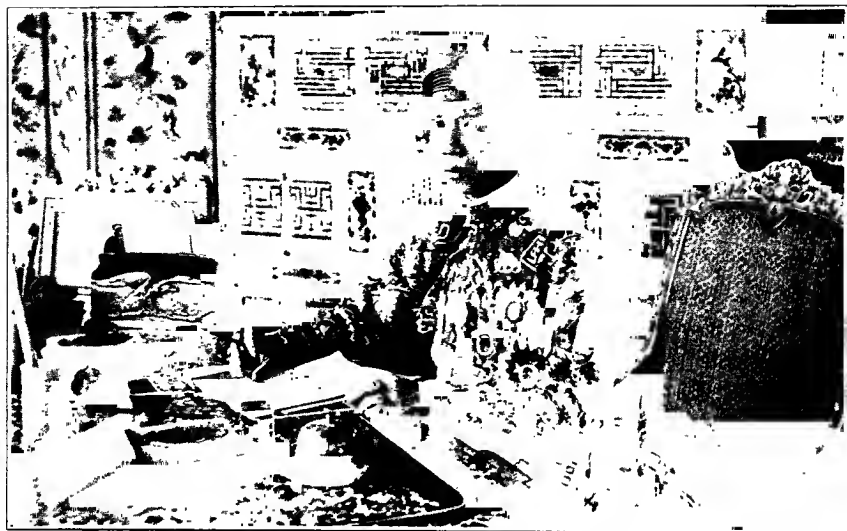
2. BLUE BAMBOO CULTIVATED FOR ORNAMENT ON THE GROUNDS OF THE CANTON CHRISTIAN COLLEGE.



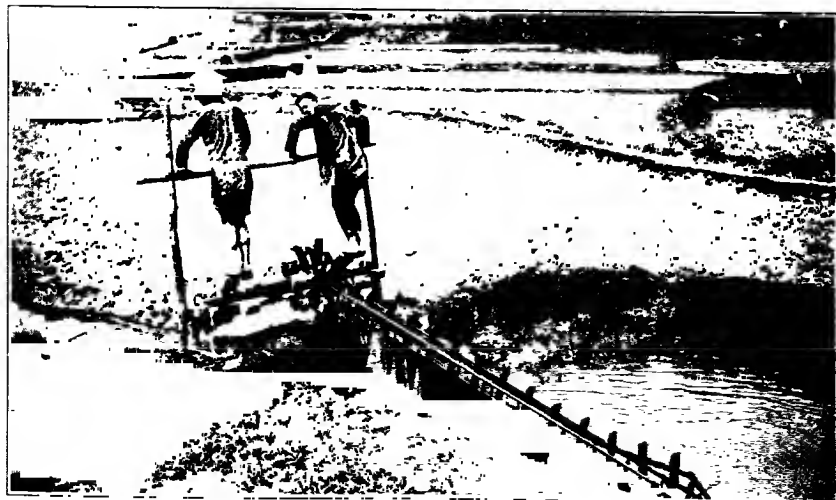
1. ROOM IN A JAPANESE HOTEL AT HAKONE. THE GUESTS SIT CROSS-LEGGED ON MATS BEFORE THE LOW TABLE UPON WHICH THE MEAL IS SERVED. A CHARCOAL STOVE IN THE REAR KEEPS THE TEA WATER HOT. THE LITTLE WOODEN FIRKIN CONTAINS THE RICE. THE SLIDING PANELS SUPPORT TRANSLUCENT PAPER INSTEAD OF GLASS.



2. TOMB OF A SAGA OR WISE MAN NEAR HAKONE, JAPAN.



1. A POST-CARD PICTURE OF THE EMPEROR OF ANAM, SHOWING THE COMMON TYPE OF HEADRESS USED BY THE MEN AT HUE. THE TURBAN CONSISTS OF SEVERAL WINDINGS OF A LONG STRIP OF BLACK CLOTH, LEAVING THE CROWN OF THE HEAD UNCOVERED.



2. A COMMON TYPE OF IRRIGATING PUMP USED IN THE RICE FIELDS OF SOUTH CHINA. THE WATER IS RAISED A FOOT OR TWO.

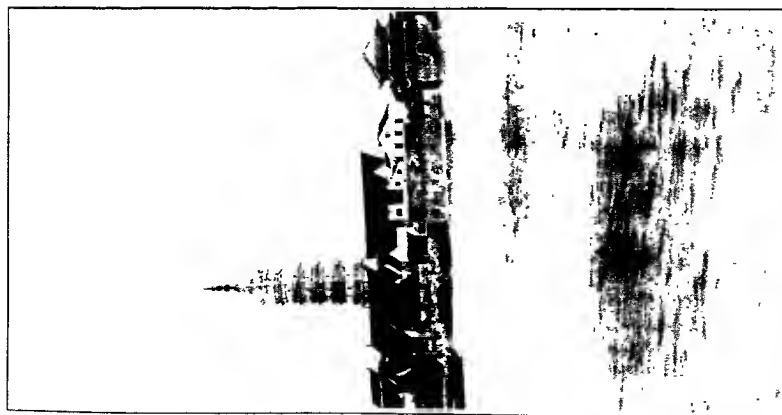
(Photograph furnished by the Canton Christian College.)



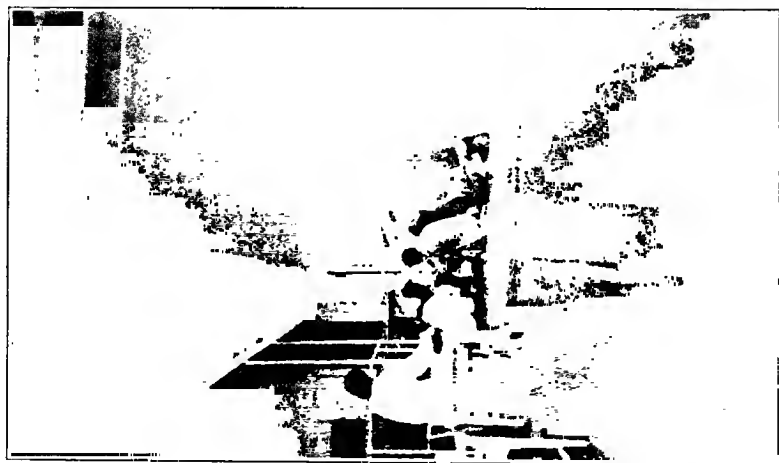
1. A POST-CARD PICTURE OF A VILLAGE IN INDO-CHINA. THE BAMBOO PLAYS AN IMPORTANT PART IN THE INDUSTRY OF THE PEOPLE.



2. A POST-CARD PICTURE OF A SCENE IN THE TOWN OF VINH, ANAM, SHOWING THE TYPE OF HUTS AND THE BROAD HATS OF THE WOMEN.



1. A PAGODA ON THE YANGTSE RIVER.



2. A STEAMER ON THE YANGTSE RIVER, SHOWING THE MEN AT DINNER.



3. A LARCH TREE NEAR TIMBER LINE ON MOUNT FUJI. THIS IS ALONG THE TRAIL TAKEN IN THE ASCENT FROM GOTEMBA. SCATTERED OVER THE GROUND ARE NUMEROUS DISCARDED STRAW SANDALS USED BY CLIMBERS ON THE CINDER SLOPES ABOVE THIS POINT.

ANT ACACIAS AND ACACIA ANTS OF MEXICO AND CENTRAL AMERICA.

By W. E. SAFFORD.

[With 15 plates.]

Among the plants of the New World which have attracted the attention of early explorers and naturalists are certain acacias armed with large spines, which serve as nesting places for intrepid little stinging ants. These spines, which occur in pairs joined at the base, bear a resemblance to the horns of animals, some of them to the spreading or incurved horns of oxen or buffaloes, others to the erect horns of certain antelopes, while others, sometimes curiously twisted, suggest those of an ibex. From the base of each pair of spines at the median point grows a bipinnate lacy fernlike leaf, which at length falls off, leaving the branches and stems of the acacias studded with the persistent thorns. These leaves bear on their petiole or main stem one or more glands, which when young secrete nectar, often in such abundance that it drops to the ground; and on the tips of many of the leaflets small waxy bodies resembling microscopic eggs or pears, which abound in oil and protoplasm. On plate 2 is shown a leaf of *Acacia cornigera* from a plant growing in one of the greenhouses of the United States Department of Agriculture, bearing on its petiole an elongated nectar-gland and on its leaflets numerous apical bodies. Both the nectar secreted by the glands and the apical bodies on the leaflets furnish the ants with nutritious food and are fed by them to their larvæ cradled in the hollow thorns of the plant. When the bush is jarred or shaken the ants come swarming out furiously to attack the intruder with their stings. Certain writers hold the theory that these plants, commonly called bull-horn acacias, have been able to enlist the ants as a body guard, furnishing them quarters and subsistence, in return for their protection against leaf-cutting ants and other enemies, and the plants have accordingly been called *myrmecophilous*, or "ant-loving." Others refuse to accept this view, declaring that the

acacias "have no more need for their ants than dogs for their fleas."¹

The first writer to call attention to the remarkable relationship between the ants and the acacias was Francisco Hernandez, the distinguished protomedico of Philip II, sent by his sovereign in 1570 to study the resources of New Spain. In the Huasteca region of northeastern Mexico he came upon a thorny tree, called by the Aztecs *Hoitzmamaxalli*, or "Forked thorn," which he described under the Latin heading *Arbor cornigera*, "Horn-bearing tree," as follows:



FIG. 1.—Branch of *Hoitzmamaxalli*. (*Acacia hernandezii* Safford) with "horns very much like those of a bull." Figured by Hernandez from a specimen growing in the Huasteca region of Mexico (1576).

the warm region of the Huasteca in localities near the Gulf coast both flat and hilly.²

On plate 3 is shown a pair of these hollowed hornlike spines, with the ants, larvae, pupae, and eggs which were taken from it.

The above description, written in Latin about the year 1575, but not published until after the death of Hernandez, was accompanied

The *Hoitzmamaxalli* is a tree with leaves resembling those of a mezquite or tamarind, yellow flowers, edible pods, and horns very like those of a bull, growing on the tree's trunk and branches. The leaves, which apparently have no savor when tasted, are reputed to be an antidote for poisons. Pounded to a paste and applied to the bites of serpents and other venomous animals, the wounds beforehand having been scarified, they are said, within a space of six hours more or less, to counteract and extract all the venom, in the meantime assuming a black color. Moreover, within the horns there are generated certain slender ants, tawny-colored and blackish, whose sting is hurtful, causing pain which persists for a whole day. The eggs of these ants, wormlike in form, reduced to a powder and inserted into the ears, likewise distilling into them the juice of the leaves, allays earache; and the juice will also cure toothache. This plant grows in the

¹ See Wheeler, W. M. Observations on the Central American Acacia Ants, in Trans. Second Entomological Congress, pp. 110-139. 1912.

² Hernandez, Francisco. Prodrómns, p. 48. 1651.

by two illustrations of the hornlike spines, one of which is herewith reproduced (fig. 1). The original figures were colored, showing the thorns to be chestnut-brown. The drawings of the pinnately-compound leaves were very crude, but the evidence furnished by the form and color of the interlocking thorns is quite sufficient to identify the plant described by Hernandez with similar plants in the United States National Herbarium collected in the same locality, still known as the Huasteca region of Mexico, a species described by the writer under the name *Acacia hernandezii*, in honor of the explorer who first called attention to it.³

These curious horn-bearing plants soon found their way to Europe, and were cultivated in the greenhouses of botanical gardens. The first species to be described botanically was one growing in the garden of George Clifford, included by Linnaeus in 1737, in his "Hortus Cliffortianus." It was afterwards found growing in its native habitat, near Laguna Verde, in the mountains of Veracruz, Mexico, in 1820, by the botanical explorer Christian Julius Wilhelm Schiede and was described 10 years later under the name *Acacia spadicigera*, which must be regarded as a synonym of Linnaeus's *Acacia cornigera*. Linnaeus's original type from the Clifford garden is shown on plate 1. A photograph of Schiede's original specimen in the Herbarium at Halle is shown on plate 4 by the side of a branch from a living plant of the same species growing in Washington. On plate 5 is shown *Acacia hernandezii* of the Huasteca lowlands, readily distinguished by its short-stemmed flower spikes, which may be likened to ears of maize, with the microscopic florets crowded on an elongated axis like grains of corn upon a cob.

A third species (fig 2) differing from both *Acacia hernandezii* and *A. cornigera*, in its much straighter yellow thorns, as well as in the form of its inflorescence and of certain little stalked bracteoles which protect the florets before they bloom, was collected by Schiede in the State of Veracruz in 1820, and named *Acacia sphaerocephala* by Schlechtendal and Chamisso.⁴

The next writer to call attention to the bull-horn acacias was Thomas Belt, in his interesting work entitled "The Naturalist in Nicaragua." In the narrative of a journey, made in 1872, from the hacienda of Olama to Matagalpa, Nicaragua, he writes as follows:

One low tree, very characteristic of the dry savannahs, I have only incidently mentioned before. It is a species of acacia, belonging to the section *Gummiferae*, with bipinnate leaves, growing to a height of 15 or 20 feet. The branches and trunk are covered with strong curved spines, set in pairs, from which it receives the name of the bull's-horn thorn, they having a very strong resemblance to the horns of that quadruped. These thorns are hollow, and

³ See Journ. Wash. Acad. Sciences 4: 358. 1914.

⁴ See Linnaea vol. 6, p. 594. 1830.

are tenanted by ants that make a small hole for their entrance and exit near one end of the thorn, and also burrow through the partition that separates the two horns; so that the one entrance serves for both. Here they rear their young, and in the wet season every one of the thorns is tenanted; and hundreds of ants are to be seen running about, especially over the young leaves. If one of these be touched, or a branch shaken, the little ants (*Pseudomyrma bicolor*, Guer. swarm out from the hollow thorns, and attack

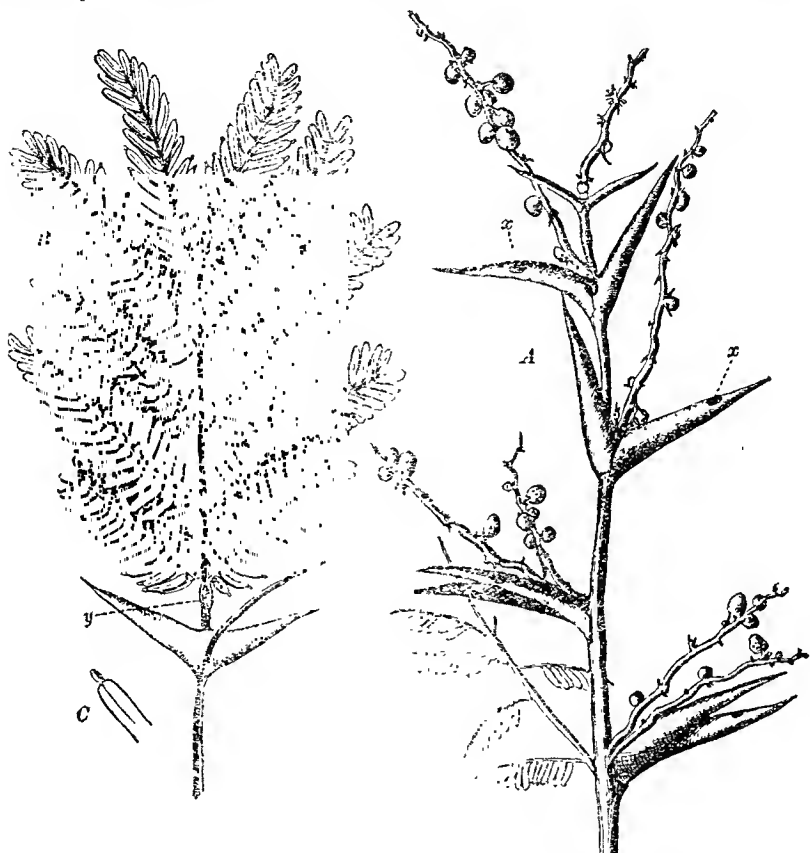


FIG. 2.—*Acacia sphaerocephala* Schl. & Cham. A, Branch of the type-specimen, showing ovoid flower heads and perforations, *x*, near the tip of the thorns made by ants; B, a pinnately compound leaf, showing nectar-gland, *y*, on the petiole; C, a single leaflet, showing terminal body rich in nutriment, fed by the ants to their young, cradled in the hollowed thorns.

the aggressor with jaws and sting. They sting severely, raising a little white lump that does not disappear in less than 24 hours,

These ants form a most efficient standing army for the plant, which prevents not only the mammalia from browsing on the leaves, but delivers it from the attacks of a much more dangerous enemy—the leaf cutting ants. For these services the ants are not only securely housed by the plant, but are provided with a bountiful supply of food; and to secure their attendance at the right time and place, this food is so arranged and distributed as to effect that object with wonderful perfection. The leaves are bipinnate. At the base of each pair of leaflets, on the mid-rib, is a crater-formed gland, which, when

the leaves are young, secretes a honeylike liquid. Of this the ants are very fond; and they are constantly running about from one gland to another to sip up the honey as it is secreted. But this is not all; there is a still more wonderful provision of more solid food. At the end of each of the small divisions of the compound leaflets there is, when the leaf first unfolds, a little yellow fruitlike body united by a point at its base to the end of the pinnule. Examined through a microscope, this little appendage looks like a golden pear. When the leaf first unfolds, the little pears are not quite ripe, and the ants are continually employed going from one to another examining them. When an ant finds one sufficiently advanced, it bites the small point of attachment; then bending down the fruitlike body it breaks it off and bears it away in triumph to the nest. All the fruitlike bodies do not ripen at once, but successively, so that the ants are kept about the young leaf for some time after it unfolds. Thus the young leaf is always guarded by the ants; and no caterpillar or larger animal could attempt to injure them without being attacked by the little warriors. The fruitlike bodies are about one-twelfth of an inch long, and are about one-third of the size of the ants; so that the ant bearing one away is as heavily laden as a man bearing a large bunch of plantains. I think these facts show that the ants are really kept by the acacia as a standing army, to protect its leaves from the attacks of herbivorous mammals and insects.

The bull's-horn thorn does not grow at the mines in the forest, nor are the small ants attending on them found there. They seem specially adapted for the tree, and I have seen them nowhere else. * * * I sowed the seeds of the acacia in my garden, and reared some young plants. Ants of many kinds were numerous, but none of them took to the horns for shelter, nor the glands and fruitlike bodies for food; for, as I have already mentioned, the species that attend on the thorns are not found in the forest. The leaf-cutting ants attacked the young plants and defoliated them; but I have never seen any of the trees out on the savannahs that are guarded by the *Pseudomyrma* touched by them, and have no doubt the acacia is protected from them by its little warriors. The thorns, when they are first developed, are soft, and filled with a sweetish, pulpy substance; so that the ant, when it makes an entrance into them, finds its new house full of food. It hollows this out, leaving only the hardened shell of the thorn. Strange to say, this treatment seems to favor the development of the thorn, as it increases in size, bulging out towards the base; whilst in my plants that were not touched by the ants, the thorns turned yellow and dried up into dead but persistent prickles. I am not sure, however, that this may not have been due to the habitat of the plant not suiting it.

These ants seem to lead the happiest of existences. Protected by their stings, they fear no foe. Habitations full of food are provided for them to commence housekeeping with; and cups of nectar and luscious fruits await them every day. But there is a reverse to the picture. In the dry season on the plains, the acacias cease to grow. No young leaves are produced, and the old glands do not secrete honey. Then want and hunger overtake the ants that have revelled in luxury all the wet season; many of the thorns are depopulated, and only a few ants live through the season of scarcity. As soon, however, as the first rains set in, the trees throw out numerous vigorous shoots, and the ants multiply again with astonishing rapidity.

The plant described above by Belt was referred to *Acacia sphaerocephala*, but this is a Mexican species which does not grow in Nicaragua. The two bull-horns which do occur in the region of Belt's

observations are *Acacia nicoyensis*, a plant allied to *Acacia sphaerocephala*, bearing large, inflated, spine-pointed pods, and *Acacia costaricensis*, with bivalved pods which split open at maturity. Both of these species were described by Dr. Heinrich Schenck.⁵ Photographs of them are reproduced in the present paper on plates 6 and 7.

CHARLES DARWIN ON BELT'S OBSERVATIONS.

In discussing the nature of extra floral nectaries Charles Darwin calls attention to the observations of Belt quoted above. After questioning Delpino's assertion that the power of secreting a sweet fluid by any extra-floral organ has been in every case specially gained for the sake of attracting ants and wasps as defenders of the plants against their enemies, and that such organs ought not to be considered simply as excretory, Darwin admits that the nectar does serve to attract insects which defend the plant and that the glands may have been developed to a high degree for this special purpose, as indicated by Belt's observations on the bull-horn acacias of Nicaragua. And he also refers to the apical bodies on the leaflets rich in oil and protoplasm, which are an additional attraction to the ants.⁶

FRANCIS DARWIN ON THE NATURE OF THE NECTAR GLANDS AND FOOD BODIES.

Francis Darwin in describing the main extra floral nectary on the petiole of *Acacia sphaerocephala*, or a species closely allied to it, compared its form to that of a flat thorn, "such as those on roses," with the top cut off; a miniature volcanic mountain with an elongated crater like a narrow trough running along the ridge summit of the gland, in which the nectar wells up like lava from the subadjacent secreting tissues, sometimes in such abundance as to overflow and drip to the ground. On plate 2 is shown a leaf of *Acacia cornigera* L. from a plant growing in a greenhouse of the United States Department of Agriculture, Washington, D. C., with a single elongated nectary on the petiole and numerous apical bodies on the leaflets. Figure 3 is a cross section through the petiole and nectar gland.

The apical appendages on the leaflets, which have been designated "Beltian bodies," measured 2 millimeters in length. Francis Darwin describes them as shaped like a pear with one side much flattened. On examination with a microscope he found them to be composed of cells containing a granular protoplasmic body in which oil globules were imbedded. Their structure he compares to that of

⁵ See H. Schenck. Die myrmekophilen Acacia-Arten. Engl. Jahrb. 50. suppl. pp. 449 to 487. 1914.

⁶ Darwin, Charles. Cross and Self Fertilization in the Vegetable Kingdom p. 404. 1877.

certain other forms of nutriment stores in the vegetable kingdom and adds:

It appears that the crater gland and the food bodies together supply nutriment sufficient to support the ants; it is evident that the latter must be considered in the light of protein stores as well as of stores of carbohydrates. We may compare them analogically with the endosperm of seeds, in which these substances are also stored.⁷

SCHIMPER ON MYRMECOPHILY.

Schimper, in his *Pflanzen-Geographia*, gives an interesting résumé of Belt's observations in a chapter entitled *Pflanzen und Ameisen*, accompanied by an illustration of the thorns, leaves, and apical

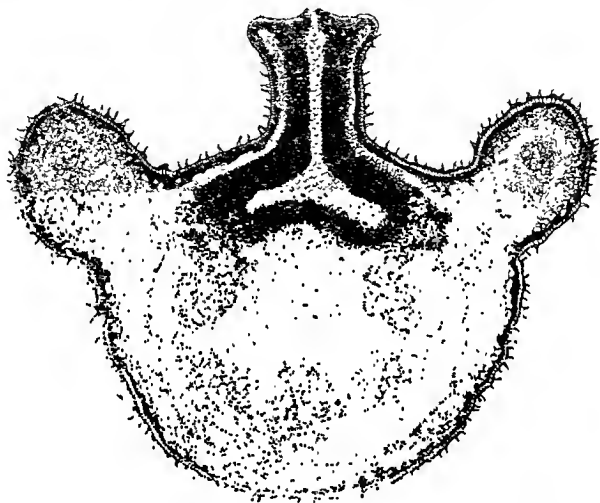


FIG. 3.—Cross section of nectar gland and petiole of *Acacia cornigera* L. made by B. J. Howard from a specimen growing in green-house at Washington. $\times 24$. Original.

bodies of a bull-horn acacia. Under the heading *Myrmecophily* he gives credit to Belt as the actual discoverer of this relationship between the ants and their hosts, calling attention, however, to the fact that the same theory was advanced by Delpino almost simultaneously and quite independently. He refers the plant used by Belt in his observations to *Acacia cornigera*, and also cites *A. sphaerocephala* as a closely allied plant which has been the subject of subsequent investigations. "Both of these acacias and, in addition to them, several other species, possess great, hollow, relatively thin-walled stipular thorns, which serve as dwellings for a certain species of virulent ant, which bores an entrance opening into them near the tip." Referring to the apical bodies on the leaflets, he continues:

These food bodies, named after their discoverer *Belt'sche Körperchen*, may be regarded from a morphological view as transformed glands. They are,

⁷ See Francis Darwin "On the glandular bodies on *Acacia sphaerocephala* and *Cecropia peltata* serving as food for ants." *Journ. Linn. Soc. Bot.* 15: 398-409. 1877.

however, distinguished from all other known glands by definite characters which may, with reasonable certainty, be regarded as special adaptations for the ants' benefit, such as greater size, longer duration, richness in albumen, and easy detachment when touched. Moreover, they lack power of secretion, at least in the later stages of their development. Of special significance in this connection is the fact that quite similar corpuscles occur in the moraceous genus *Cecropia* and the acanthaceous genus *Thunbergia* and are also associated with protective ants. The like has never been observed in connection with other plants. In addition to these corpuscles, a nectary situated at the base of the leaf-stalk yields a fluid rich in sugar.*

In addition to the ant acacias of eastern Mexico and Central America mentioned above, several beautiful and striking species have been discovered, and two or three species supposed to be identical with them have proved to be distinct. On the shore of Manzanillo Bay, State of Colima, Mexico, a species remarkable for its broad polished, mahogany-colored thorns was collected about the year 1837 by Dr. Richard B. Hinds, R. N., surgeon of H. M. S. *Sulphur*, which was described by Benthams in 1842, and named *Acacia hindsii* in honor of its discoverer.⁸ On plate 8 is shown a figure of this species, collected in the same locality as Doctor Hinds's original specimen. Its thorns have been likened to an inverted military chapeau in shape. This may be called the broad-thorn of Mexico. Closely allied to it is the more recently described *Acacia bursaria* Schenck of Guatemala, with still broader thorns. Contrasting with these species in its polished light-colored V-shaped thorns, but resembling them in the form of its curved pods, is *Acacia tepicana* (pl. 9) from Acapomete, Tepic. Two other handsome species are *Acacia collinsii* (pl. 10) from Chiapas, southern Mexico, and *Acacia nelsonii* (pl. 11) from the vicinity of Acapulco, the first remarkable for its polished, dark-colored, twisted thorns, the second with pale-colored horns shaped like a crescent moon. Last of all comes the beautiful *Acacia cookii* from Alta Verapaz, Guatemala, with globose heads of flowers (pl. 12) and remarkably long dehiscent pods (pl. 13), very different from all species hitherto described.

The various species of ant acacias, though resembling one another in the possession of extrafloral nectar glands, apical food bodies, and certain other features, form several distinct natural groups, as shown in figure 4, based chiefly upon the form of their seed pods. In the first group (*a*), which I have called the "Spine pods," the fruits are inflated, thin-shelled, indehiscent pods terminating in a slender sharp spine¹⁰ and containing two rows of seeds (*a'*) embedded in a sweetish yellow edible pulp. In the second group (*b*) the pods are not spine-tipped nor indehiscent, but split open along two sutures like

⁸ Schimper, *Pflanzen-Geographie* pp 154-155. 1898.

⁹ *Acacia hindsii* Benthams, *Lond. Journ. Bot.* 1. 504. 1842.

¹⁰ To this group belongs *Acacia cornigera*, characterized by Hermann in his *Paradisus Batavi* Prodromus (1689) as *Acacia americana carnigera siliquis in spinam abeuntibus*

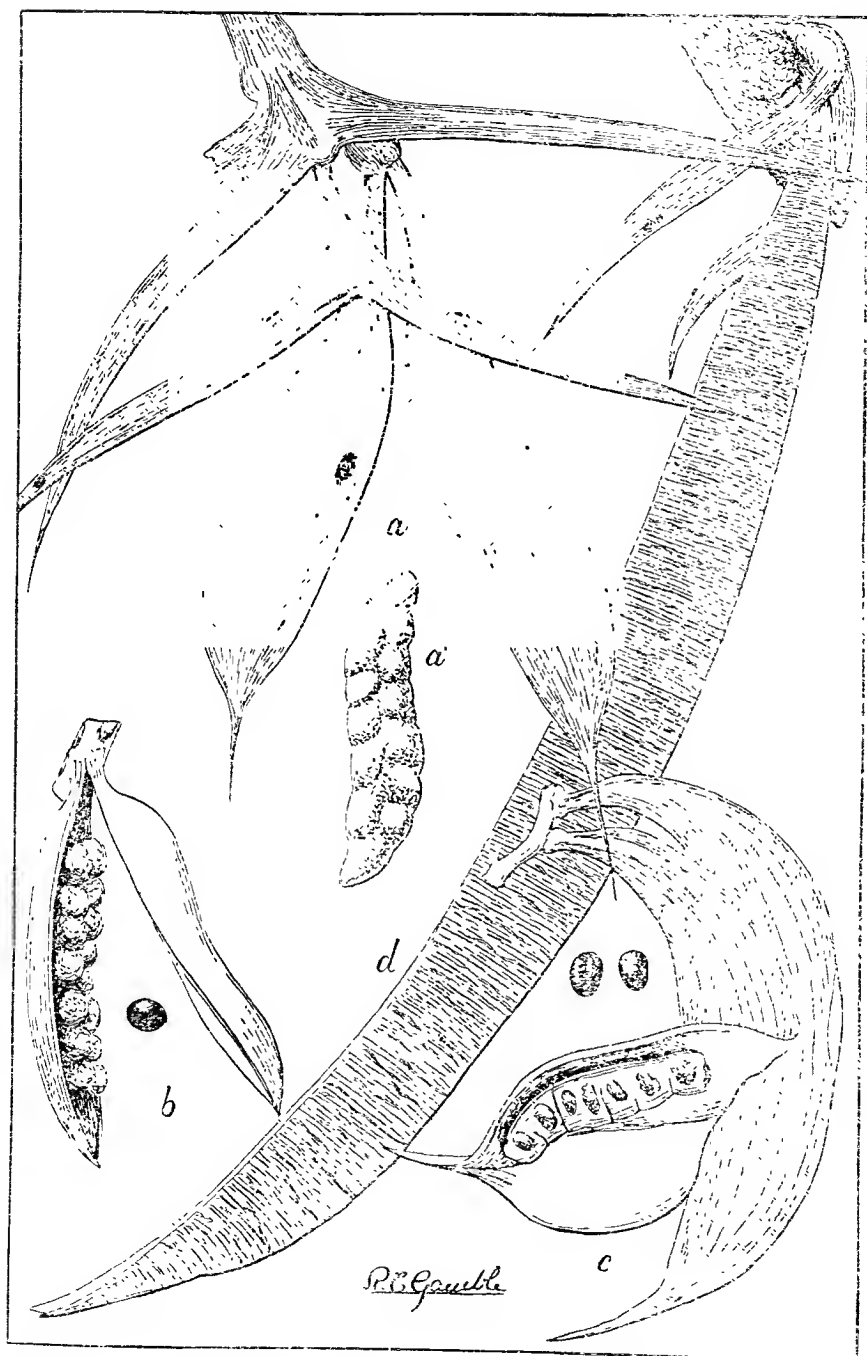


FIG. 4.—Pods of ant acacias, used as a basis of their classification. *a*, *Acacia cornigera*, indehiscent and spine-tipped; *a'*, seeds of the same enveloped in sugary pulp; *b*, *Acacia collinsii*, pods dehiscent along 2 sutures; *c*, *Acacia tepicana*, similar pod with 1 suture; *d*, *Acacia cookii*, Globuliferae group, with large 2-valved pods.

the legumes of a bean, showing the seeds in two rows, embedded in sweetish pulp; this group I have called the "Bean pods" or Leguminiferae. The third group (*c*) has curved pods, with the seeds in a single row, embedded in a feltlike pulp; this group I have called the "Simitar pods," or Acinaceae. The last group (*d*), distinguished by its long two-valved legumes, I have called the Globuliferae, on account of the globose shape of the flower heads (pls. 12 and 13).

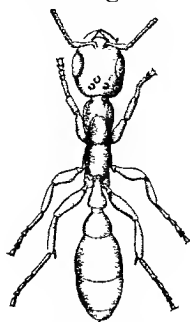


FIG. 5.—Acacia ant, *Pseudomyrma belti*, var. *fulvescens*, worker; showing elbowed antennae and sting. From Tanquian, state of San Luis Potosi, Mexico. $\times 6$.

ACACIA ANTS OF MEXICO.

In 1908, through the kindness of Don Luis G. Cuevas, of San Luis Potosi, to whom American scientists are indebted for many favors, I received several colonies of living ants in the thorns of bull-horn acacias collected at Tanquian in the district of Tancanhuitz, State of San Luis Potosi. When the box was unpacked in my office, the furious little insects came swarming out, some of them climbing up my legs and stinging me severely.

All of these ants came from the thorns of *Acacia sphaerocephala*, easily distinguished from *A. hernandezii* of the same region by their pale yellow color and their less widely spreading and straighter form. The ants of a tawny yellow or reddish color with darker abdomens, proved to be *Pseudomyrma belti* var. *fulvescens*, closely allied to the typical darker colored *Pseudomyrma belti*. Specimens of them deposited in the collection of the Bureau of Entomology were forwarded by Mr. S. A. Rohwer to Professor Wheeler, who kindly identified them. Beautiful photographs of workers and a male ant were made for me by Mr. H. S. Barber, of the Bureau of Entomology (pl. 14). Drawings are also shown in figures 5 and 6 to illustrate the structure of these interesting insects. As shown in these figures both the male and the workers

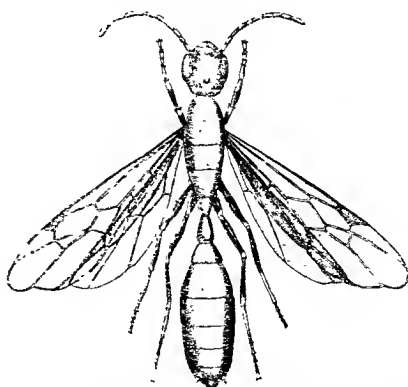


FIG. 6.—Acacia ant, *Pseudomyrma belti*, var. *fulvescens*, male; showing long curved antennae and pair of cerci at the end of the abdomen. $\times 6$.

have the abdomen or gaster connected to the thorax by means of two slender segments technically known as the petiole and post-petiole. The longer and more slender male is distinguished by a pair of *cerci* at the

posterior extremity of his body as well as by the form of his antennae, which are not elbowed like the workers', but made up of numerous beadlike segments. Both the male and the workers have, in addition to the large compound eyes on the sides of the head, three small simple eyes, called ocelli, on top of the head. These are scarcely visible in the photographs but are shown in the drawings.

Ants of the same variety, *Pseudomyrma belti* var. *fulvescens*, were collected by Dr. E. A. Schwarz near Tampico, in January, 1910. In a paper read before the Entomological Society of Washington he fully corroborates the original observations of Belt as to the efficiency of the ants as a bodyguard, in defending their host from men, cattle, and insects. The acacias were extremely abundant, bordering the roadsides and covering great stretches of the sandy hammock along the seabeach. The principal, if not the only species, of that locality was *Acacia sphaerocephala*, every bush of which was tenanted by *Pseudomyrmas*. At the time of his visit, the latter part of December and the first part of January, the bushes were covered with flowers and young buds. Doctor Schwarz was interested chiefly in collecting beetles. He found a small weevil abundant, the perfect insects on the inflorescences both mature and immature, the larvae in the seeds. They seemed to be the only insects which the ants would tolerate. When Doctor Schenck beat the bushes with his collecting net the ants would swarm out in great numbers and sting him. The only way he could collect successfully was to make a preliminary survey of the space beyond the bushes and then rush through the thicket at full speed beating the bushes with his net in passing and escaping before the ants had time to issue from the thorns. "I did not mind the thorns at all," he declared, "but the stings of the ants were something fierce." Only one species of beetle was collected by him, a weevil at first believed to be a species of *Bruchis*. A more recent study of it, however, has led Mr. J. C. Bridwell to place it in a genus apart from *Bruchis*, from which it appears to be distinguished by the possession of an ovipositor.

In close proximity with the living trees was a dead acacia, which the ants had quite deserted. It had in all probability been killed by some insect boring into its roots, a fact which indicates that the ants are powerless to protect their host against the attacks of an underground enemy. The roots penetrated the ground to a great depth and resisted all attacks to pull them out; but Doctor Schwarz brought back to Washington parts of the trunk and larger branches infested by beetle larvæ and parasitic Hymenoptera, from which he bred perfect insects.

Wishing to establish a colony of *Pseudomyrmas* on our growing *Acacia cornigera* in one of the greenhouses of the Department of Agriculture, I wrote to Mr. J. M. Cuaron of Tampico, Mexico, asking him to send me a few branches of the species growing in that vicinity with thorns occupied by living ants. In a few days I received from him a box containing several branches of *Acacia sphaerocephala*. On opening it I found it swarming with belligerent little ants. Without delay I took the box to the greenhouse and lodged it in the branches of our little tree. Almost immediately the ants took possession. I saw one little male visit several thorns in succession, vibrating its wings and hanging on to the tip of the thorn by his anterior legs, while he rubbed the tip of his abdomen against the thorn. The next morning I found the workers engaged in gnawing holes in the thorns, invariably in a single thorn of a pair and always near the tip. The following day there were two thorns thus perforated and I saw the workers carrying the larvae into one of them. The ants, however, do not appear to be quite at home on their new host plant, possibly because there may be a lack of food and perhaps because many of the neighboring plants have been sprayed with poisonous mixtures from time to time, to free them from scale insects and other parasites. One thing is certain, the enlargement of the acacia thorns is not wholly due to the ants, for many of the thorns on my tree were quite large and hornlike before the ants had been placed upon them. My experiment established the fact that the little colonies in the individual thorns are not independent of one another, but larvae, pupae, and ants may be transferred from one thorn to the other without opposition from ants already established in the new thorn. I had hoped that the ants would free the acacia of certain scale insects with which it was infested, but I was disappointed to see them passing by these insects apparently without taking any notice of them. Many of the thorns are now tenanted, and I am looking forward with interest to see whether my colonization scheme will be a success. Plate 3 shows a pair of the thorns from Mexico, which I photographed after having chloroformed the ants, all of which, in the various stages, occupied the thorn photographed.

That a single species or variety of *Pseudomyrma* is not restricted in its choice of a home to trees of the same species was demonstrated by the observations of Mr. Guy N. Collins in the State of Chiapas, southern Mexico, where he collected several varieties of *Pseudomyrma belti*, but not the typical form, which is black. Most of the specimens collected by Mr. Collins were found by Professor Wheeler to be transitional forms intermediate between the dark-colored type and the pale variety *fulvescens*, to which my Tampico specimens belong.

In addition to the true acacia ants, all of which are *Pseudomyrmas*, Mr. Collins collected two other species of ants, *Dolichoderus championi* and *Cryptocerus pallens*, which also nest in hollow twigs or in other small vegetable cavities. *Cryptocerus* takes its generic name from its hidden antennae, which easily serve to distinguish it from the *Pseudomyrmas* with their conspicuous spreading elbowed antennae. In the twisted thorns of *Acacia collinsii* (see plate 10) growing at San Sebastian, near Tuxtla, Mr. Collins collected both *Pseudomyrma belti* var. *fulvescens* and *Cryptocerus pallens*, the latter in the old thorns which had been abandoned by the former. He collected another form of *Pseudomyrma belti*, transitional between the type and the variety *fulvescens*, in the broad thorns of *Acacia hindsii* at a locality not far from the Pacific coast of Chiapas and also in those of *Acacia nicoyensis* growing near Pichulcalco.

PSEUDOMYRMAS OF NICARAGUA AND COSTA RICA.

To His Excellency Gen. Emiliano Chamorro, President of Nicaragua, I am indebted for specimens of ants collected from the spines of an acacia growing at Granada, which proved to be *A. costaricensis*. At his request three species were sent to me by Senor J. B. Mondragon, labeled "Hormiga negra brava," "Hormiga roja," and "Hormiga degenerada." Photographs of them are shown on plate 15. They were identified by Professor Wheeler; the "brave black ant" as the typical *Pseudomyrma belti*, the "red ant" as *Pseudomyrma belti* var. *fulvescens*, and the small broad "degenerate ant" as *Crematogaster brevispinosa*. Of the last named Professor Wheeler says:

I do not believe that the *Crematogasters* puncture the acacia thorns, but if Belt claims that they do he probably observed them in the act. Wherever I have seen them in connection with acacia thorns they have been mereinquillines living in old thorns abandoned by *Pseudomyrmas*. *Crematogaster* has a sting, but it is small and not painful.

From Costa Rica at least three distinct species of *Pseudomyrmas* are recorded by Don Anastasio Alfaro, director of the National Museum at San José. These he distinguishes by their colors as "*hormigas negras, rojas, y amarillas*," or black, red, and yellow ants. They were described by Professor Emery of Bologna; the black species, identical with my own species from Nicaragua, as *Pseudomyrma belti*, the red as *Pseudomyrma spinicola* and the yellow as *Pseudomyrma nigrocincta*.¹¹ Their habits, as described by Señor Alfaro, are identical with those of their Mexican congeners.

Recent studies of Doctor Wheeler and Professor Bailey of the Bussey Institution on the feeding habits of the *Pseudomyrmas* have

¹¹ C. Emery, Zur Biologie der Ameizen, Biolog. Centralblatt 11: 165-180. 1891.

shown that the food pellets taken from their pouches usually contain fragments of insects, pollen of various plants, and portions of Beltian bodies from the tips of the leaflets of the host plant. Larvae of this

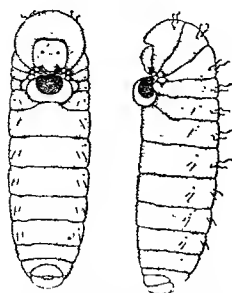


FIG. 7.—Larva of an acacia ant, *Pseudomyrma gracilis*, showing food-pouch, or trophothylax. Enlarged. After Wheeler and Bailey.

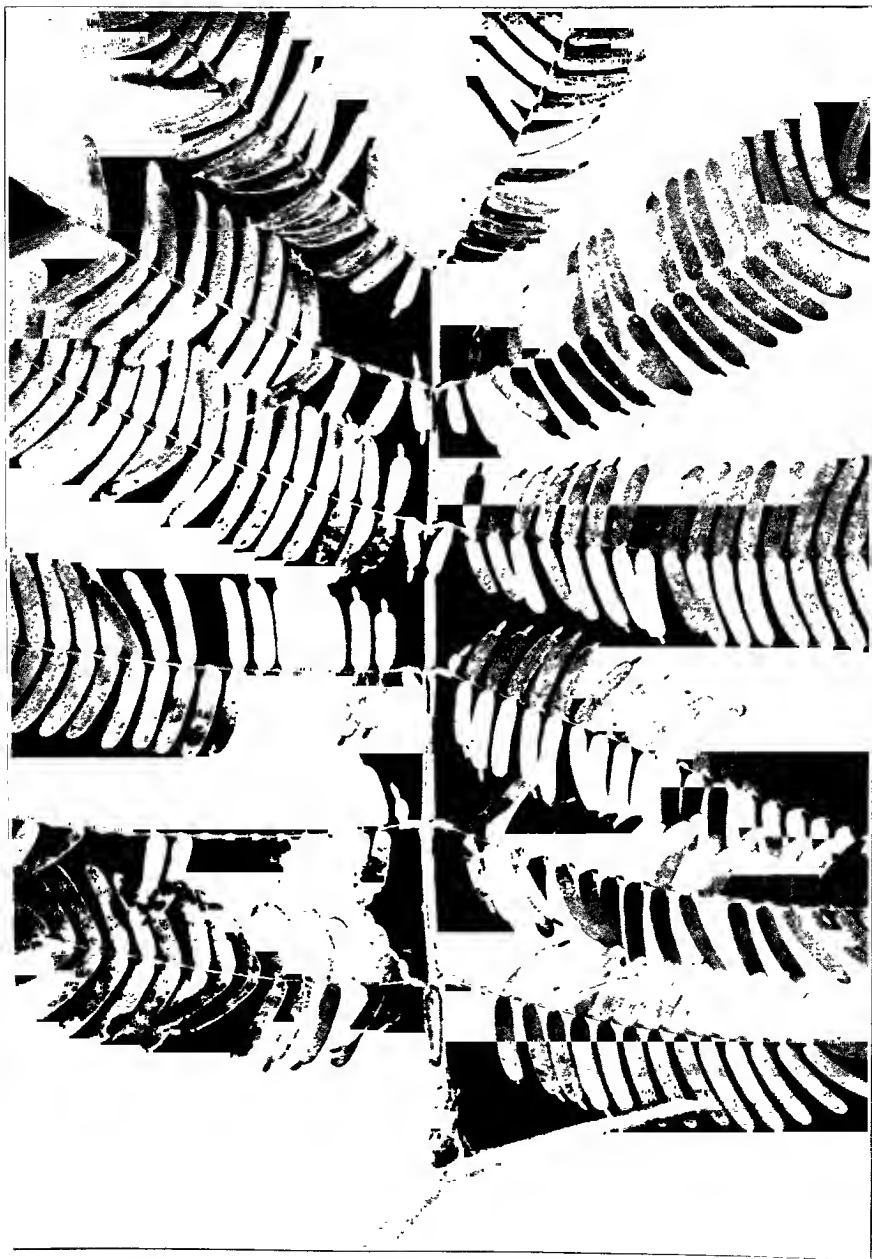
genus are shown herewith (fig. 7). They are straight and cylindrical, rounded at each end, and composed of sharply defined segments, with a tough transparent skin, large squarish head, and stout mandibles. The most interesting feature of all is the food pouch, or *trophothylax*, borne on the first segment of what will eventually become the abdomen of the ant. From this pouch, which opens toward the mouth parts, the food pellets to be analyzed were taken.¹²

In conclusion I would call attention to the great work of Professor Wheeler, "Ants, their structure, development, and behavior," issued by the Columbia University Press in 1913, and to his more recent and equally fascinating articles on "Social life among the insects," appearing in the *Scientific Monthly*, beginning June, 1922.

¹² See W. M. Wheeler and I. W. Bailey. The Feeding habits of Pseudomyrmecine and other ants. *Trans. Am. Philosophical Society*. 235-279. 1920.



ACACIA CORNIGERA. TYPE SPECIMEN FROM THE CLIFFORD GARDEN IN HOLLAND (1737). NOW IN THE LINNAEAN HERBARIUM, BRITISH MUSEUM. NEARLY ONE-HALF NATURAL SIZE. ORIGINAL.



ACACIA CORNIGERA. LEAF OF A GROWING PLANT AT WASHINGTON, WITH CRATER-LIKE, ELONGATED NECTAR GLAND ON PETIOLE AND NUMEROUS "BELTIAN BODIES" ON TIPS OF LEAFLETS, WHICH ARE GATHERED BY THE ANTS AND FED TO THEIR YOUNG. X 1'. ORIGINAL.



ACACIA SPHAEROCEPHALA. THORN FROM TAMPICO, MEXICO, WITH THE ANTS, LARVAE, AND PUPAE (*PSEUDOMYRMA BELTI* VAR. *FULVESCENS*) TAKEN OUT OF IT. RECEIVED FROM J. M. CUARON. X 2. ORIGINAL.



^a



^b

ACACIA CORNIGERA. ^a, HERBARIUM SPECIMEN COLLECTED BY SCHIEDE IN MEXICO AND DESCRIBED BY SCHLECHTENDAL AND CHAMISO UNDER THE NAME ACACIA SPADICIGERA; ^b, LIVING SPECIMEN FROM GREENHOUSE AT WASHINGTON. FLOWER SPIKES WITH LONG STEMS, CONTRASTING WITH THE SUBSESSILE SPIKES OF A. HERNANDEZII. NATURAL SIZE.



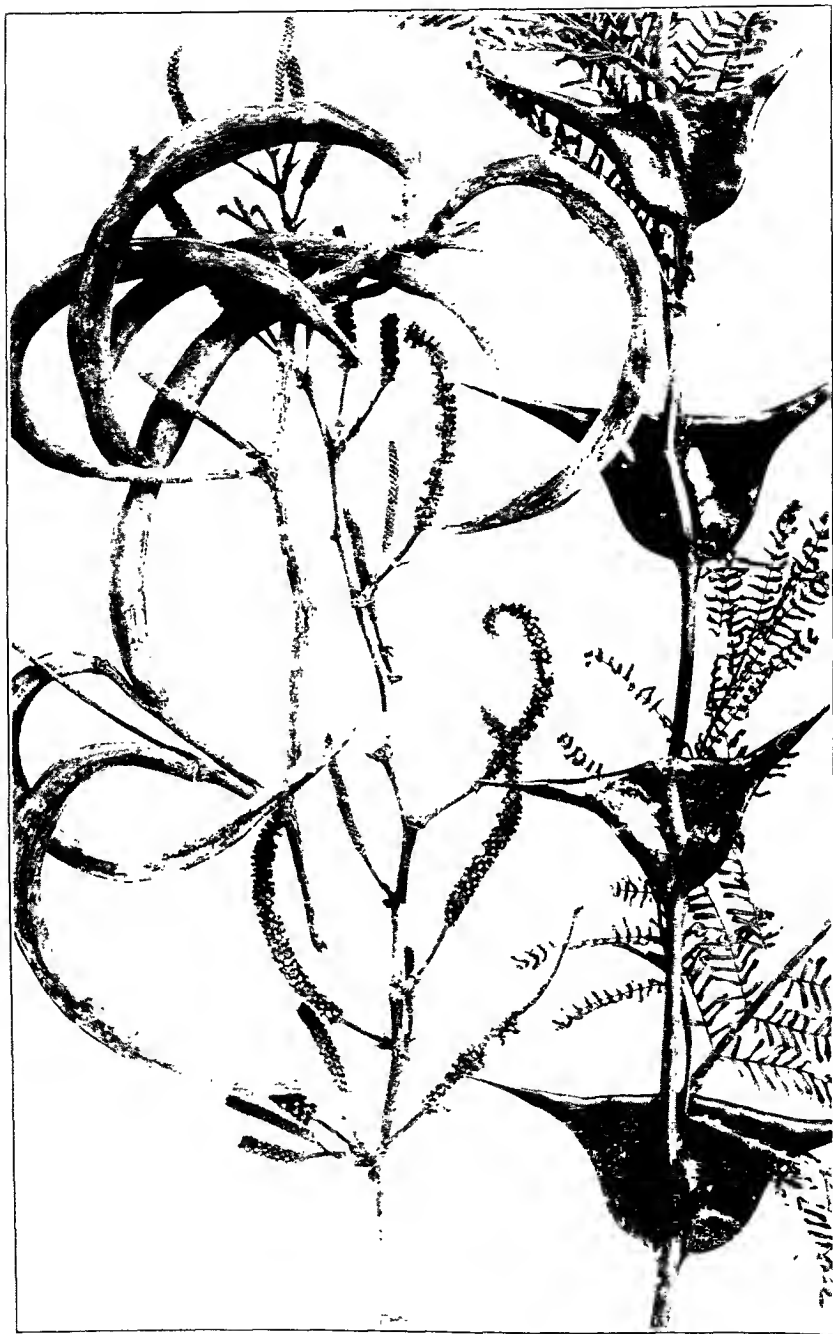
ACACIA HERNANDEZII, WITH SPREADING THORNS, LIKE BULL HORNS, SUBSESSILE FLOWER SPIKES, INDEHISCENT PODS, AND DOUBLE ROW OF SEEDS EMBEDDED IN SUGARY PULP, FROM THE MEXICAN HUASTECA REGION. NATURAL SIZE. ORIGINAL.



ACACIA NICOYENSIS. ONE OF THE SPECIES OBSERVED BY BELT IN NICARAGUA. FLOWER SPIKES USUALLY SOLITARY, FLORETS BORNE ON A THICK CYLINDRICAL RECEPTACLE RESEMBLING A MINIATURE CORNCOB. FROM NICOYA, COSTA RICA. NATURAL SIZE. ORIGINAL.



ACACIA COSTARICENSIS, A SECOND SPECIES OBSERVED BY BELT IN NICARAGUA. FLOWER SPIKES FASCICLED, FLORETS BORNE ON A SLENDER PLIABLE RECEPTACLE. NATURAL SIZE. ORIGINAL.



ACACIA HINDSII, THE BROAD-THORN OF THE PACIFIC COAST OF MEXICO. FLORETS IN LAX FLEXIBLE SPIKES, PODS SCIMITARLIKE, OPENING BY A SINGLE SUTURE. SPECIMEN FROM THE TYPE LOCALITY, MANZANILLO BAY, STATE OF COLIMA. NATURAL SIZE. ORIGINAL.



ACACIA TEPICANA, FROM TEPIC, MEXICO, SHOWING ITS RECURVED ACUMINATE PODS, OPENING BY A SINGLE SUTURE, AND ITS SINGLE ROW OF SEEDS EMBEDDED IN FELTLIKE PULP. NATURAL SIZE. ORIGINAL.



ACACIA COLLINSII, A SPECIES WITH TWISTED SPINES, TWO-VALVED DEHISCENT PODS, AND SEEDS IN TWO ROWS. PHOTOGRAPH OF TYPE MATERIAL. CHIAPAS, SOUTHERN MEXICO. NATURAL SIZE. ORIGINAL.



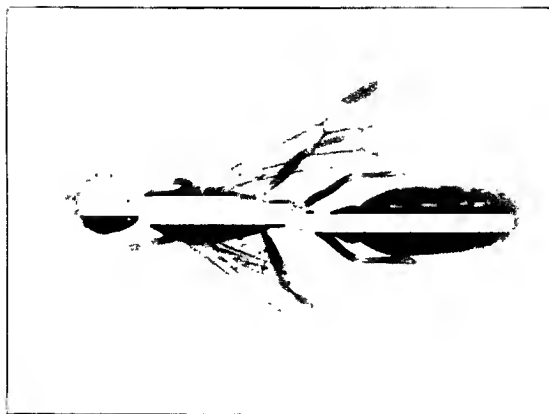
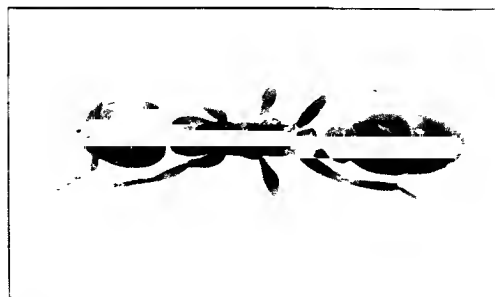
ACACIA NELSONII, A SPECIES WITH CRESCENT-SHAPED SPINES, LONG-STEMMED FLOWER SPIKES AND FLORETS BORNE ON A VERY SLENDER RECEPTACLE. PHOTOGRAPH OF TYPE SPECIMEN, FROM ACAPULCO, MEXICO. NATURAL SIZE. ORIGINAL.



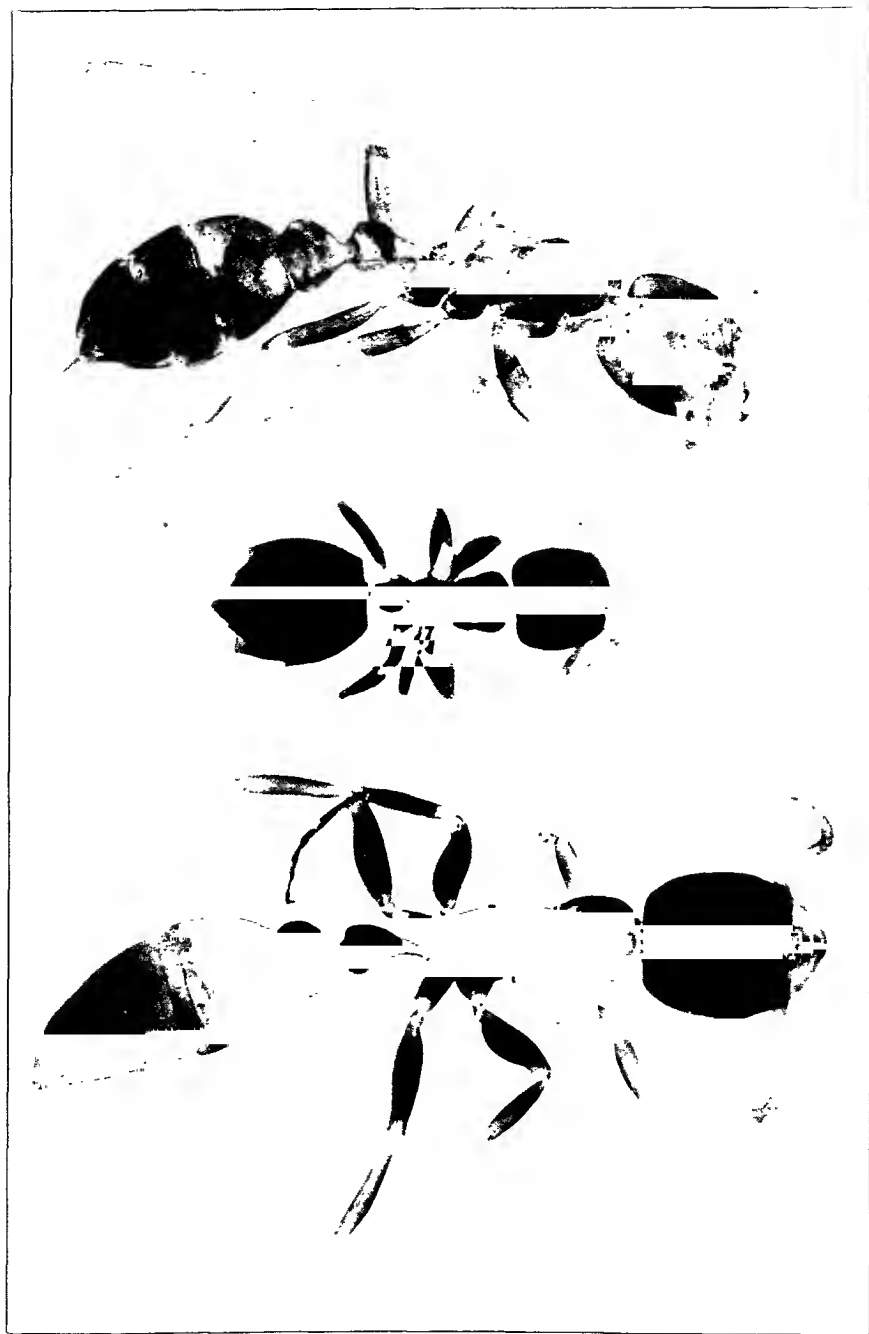
ACACIA COOKII, REMARKABLE FOR ITS CLUSTERS OF GLOBOSE FLOWER HEADS; FLORETS BORNE ON KNOBLIKE RECEPTACLES. PHOTOGRAPHED IN FIELD, MOUNTAINS OF ALTA VERAPAZ, GUATEMALA, BY O. F. COOK. NATURAL SIZE.



ACACIA COOKII, PODS DIFFERING FROM THOSE OF OTHER GROUPS IN THEIR GREAT SIZE AND WOODY TEXTURE. SPECIMENS FROM ALTA VERAPAZ, GUATEMALA. NATURAL SIZE. ORIGINAL.



ACACIA ANTS FROM THE HUAATECA REGION OF MEXICO, *PSEUDOMYRMA BELTI* VAR. *FULVESCENS*, FROM THORNS OF *ACACIA SPHAEROCEPHALA*, RECEIVED FROM DON LUIS G. CUEVAS, OF SAN LUIS POTOSI. WINGED MALE IN THE CENTER, WITH LONG SLENDER FLEXIBLE ANTENNAE. ON THE LEFT AND RIGHT, WINGLESS, STINGING WORKERS WITH ELBOWED ANTENNAE. PHOTOGRAPHS BY H. S. BARBER. ENLARGED 7.5 DIAMETERS.



ACACIA ANTS FROM NICARAGUA, INHABITING THE HOLLOW THORNS OF ACACIA COSTARICENSIS. AT THE TOP, ACACIA BELTI VAR. FULVESCENS CALLED "HORMIGA ROJA"; IN THE CENTER, CREMATOGASTER BREVISPINOSA, "HORMIGA DEGENERAOA"; BELOW, PSEUDOMYRMA BELTI, "HORMIGA NEGRA BRAVA." RECEIVED FROM PRESIDENT CHAMORRO OF NICARAGUA. ENLARGED NEARLY 14 DIAMETERS. ORIGINAL.

THE FALL WEBWORM.

By R. E. SNODGRASS,

Office of Fruit Insect Investigations, Bureau of Entomology.

[With 2 plates.]

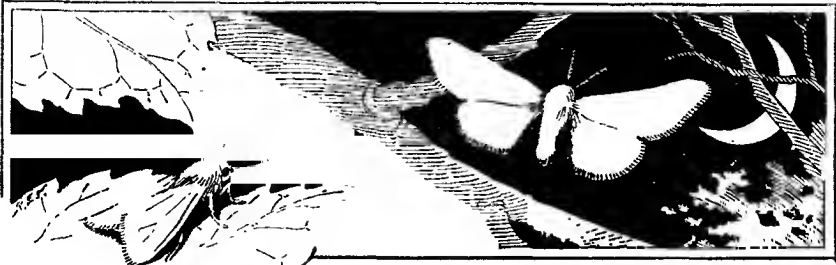


FIG. 1.—Moths of the fall webworm (natural size).

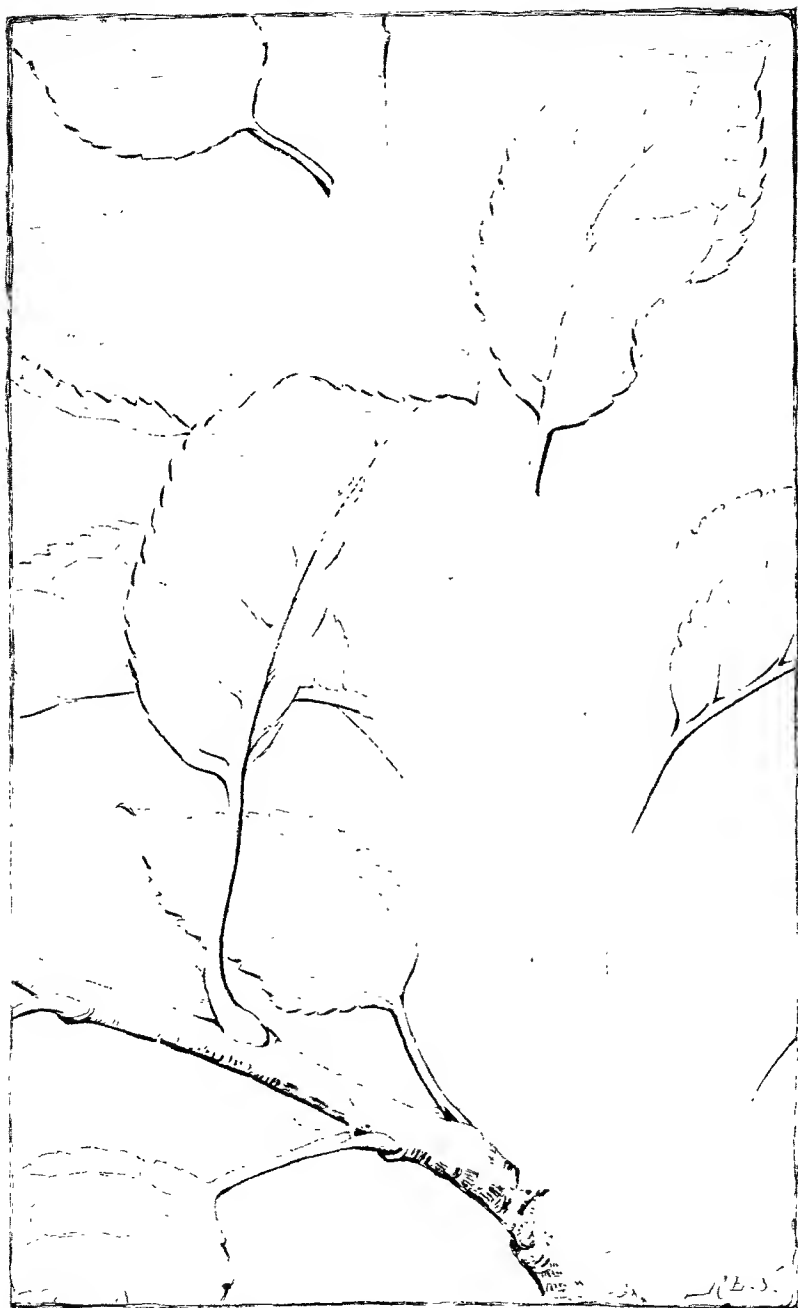
Could insects think and express their thoughts in terms that we could understand we should probably hear complaints from them of woods and fields disfigured by our barns and country houses and of great areas devastated by our factories and towns. However, since it happens that we are the ones that do the thinking, it is we that express our thoughts in these same terms against the insects and their works. People still ask why pests were made to annoy us and to destroy our crops. But such questions imply a too egotistical view of the situation. All of us, men and insects, are on the earth for our own ends, and friction arises wherever interests overlap. A caterpillar claims a certain tree as its natural food and habitat, but we assert our property rights and proceed to drive the caterpillar out. Yet, though we never so intended, we have vastly improved living conditions for many insect species by furnishing them a far greater acreage of their favorite food plants than nature ever provided. As a consequence they multiply in spite of our constant war against them.

In June silvery white bags of glistening silk appear amongst the foliage of city, orchard, and woodland trees, each inclosing twigs and leaves. As the season advances the bags increase in size, the leaves within them die, and by fall they become objects of disgusting ugliness, each perhaps spreading over several square feet of area. These bags are the homes of the fall webworm, hairy caterpillars which are the progeny of a small, white, night-flying moth (fig. 1)

that earlier in the season laid her eggs on a nearby leaf (pl. 2, A). Since the caterpillars themselves are most interesting creatures, it is truly regrettable that their architecture does not possess greater aesthetic merit. But, though we can not admire its art, let us study the worm.

Each bag is the domicile of one large family, and much of the time it presents scenes of great activity. Most of the inhabitants are usually busy spinning and weaving, laying extra sheets of silk on walls already substantial, constructing stays and partitions within, or running out scaffolding to neighboring leaves and twigs which will soon become the foundation for an extension to the web. At the same time, many others are within feeding on the surfaces of the inclosed leaves, preparing to take the places of the present workers when they lay off for dinner. A few apparently lazy ones, however, may be stretched out inside the tent asleep; but these are really those that have grown to the point where their skins have to be shed, and this process must be preceded by a rest. The bag has to be enlarged daily, for, unlike human families which bring their food into their houses for consumption, the webworm families build their houses around their food. Since families are large and appetites never appeased for long, this arrangement entails almost constant remodeling and enlargement of the dining room. As a consequence the house ever lengthens and expands, taking in more and more fresh leaves in one direction, while deserted chambers string out in the wake of the moving family, containing the dead and dying remains of leaves and a litter of refuse and molted skins.

The moths of the fall webworms appear in the spring, which is to say, they emerge at this season from the chrysalids in the winter cocoons, as will be described later. The exact date of their emergence depends on the season and the latitude. They come out sooner in the South than in the North, and appear earlier anywhere in a warm season than in a late one. But in general they are about in May, when, after mating, the females proceed to lay their eggs, selecting for this purpose a leaf on some tree that will be proper food for the future caterpillars. Most species of caterpillars are very fastidious in their taste and will feed only on certain kinds of plants. The parents of such have to know these preferences of their progeny and most of them are very particular to select the right variety of herb, shrub, or tree on which to lay their eggs, so that the infant caterpillars will not have to travel far to find a first meal to their liking. But, the webworm caterpillars having small choice in a large menu, including nearly all deciduous shrubs and trees, the webworm mothers have little to do beyond suiting their own convenience.



WEB OF YOUNG WEBWORMS SPREADING OVER SEVERAL LEAVES. REMAINS OF EGGS FROM WHICH THE FAMILY HATCHED SEEN ON UNDER SIDE OF UPTURNED LEAF.



THE FALL WEBWORM. *A*, APPLE LEAF WITH PATCH OF EGGS ON UNDER SURFACE, AND THE MOTH THAT LAID THEM; *B*, PART OF A WEBWORM WEB INCLOSING LEAVES ON AN APPLE TWIG; *C* A MATURE WEBWORM CATERPILLAR WHICH HAS LEFT THE WEB; *D*, A COCOON ON THE GROUND AMONGST DEAD LEAVES; *E*, THE PUPA OR CHRYSALIS TAKEN FROM A COCOON; *F*, AN ADULT WEBWORM MOTH.

They generally select for their eggs a leaf toward the tip of a twig, which suits the caterpillars best since they prefer to work toward the base of a branch. The eggs are usually stuck to the under side of the leaf and, when all are laid, they form a flat mass of closely placed spheres covering an irregular area one-fourth to one-third of a square inch in extent, which may include as many as 500 eggs, though 200 to 300 is a more usual number. The finished egg patch has a fuzzy white appearance (pl. 2, A), because it is covered with a soft matting of fine scales rubbed from the under surface of the body of the moth. The eggs (fig. 2) are glued to the leaf by a gummy substance exuded when they are laid. Each is spherical and, when fresh, is of a pale, glistening greenish color. The surface is roughened like the skin of an orange, except on top where there is a round central smooth area. The sphere has a diameter of about one-fiftieth of an inch.

A moth was observed at Wallingford, Conn., laying her eggs the 1st of June. These eggs began to hatch on the 15th, but 24 hours

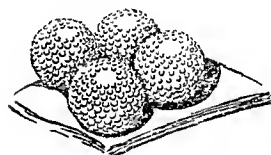


FIG. 2.—Four eggs on a piece of leaf (greatly enlarged).

before hatching they exhibited a change of color, turning from the pale greenish tint to a leaden gray. Those that were laid first were the first to change, and as the hatching progressed the dark color gradually spread across the mass. The hatching extended over three days. Each inclosed caterpillar liberates itself by eating a hole in

the top of its shell large enough to admit its head and shoulders. Then it calmly crawls out, straightening and stretching to nearly a twenty-fifth of an inch in length, and leisurely wanders about over the eggs or explores the immediate neighborhood of the leaf. The first to come out remain about the egg patch waiting for the others. Being communists by nature they appear to feel, even at this early stage, that they are helpless as individuals. They while away the time with a little nibbling at the empty eggshells and with trying their spinnerets by weaving a few threads over the eggs and the near part of the leaf. By the time the majority are out, however, the eggs are often covered with a delicate sheet of silk and frequently a web is spun over a considerable area of the leaf. But with those observed by the writer the crowd usually migrated in a mass to the upper surface of the leaf or to an adjacent leaf before starting the first regular tent. Here the tiny creatures appear to pile up in a writhing squirming mass, all inextricably tangled in an intricate network of threads which they are spinning and weaving as if their young lives depended on its shelter. The mass of silk grows rapidly and before

long fills the hollow of the leaf (fig. 3.) A few caterpillars always work on top of the structure, roofing it over with a smooth sheet of web which is anchored along both edges of the leaf. The network beneath soon becomes peppered with blackish grains of frass, showing that the appetities of the workers have already been attended to, and, if we look, we are likely to see that one shift is now laid off and is feeding on the surface of the leaf beneath the tent as industriously as the other is spinning and weaving above. As belated members of the family hatch from the eggs they follow the trail of the others to the web and join the crowd.

In a day or so the edges of the webbed leaf become strongly rolled upward, the hollow being entirely filled with web and perhaps the



FIG. 3.—First web of the young caterpillars, spun over the upper surface of a leaf.

whole leaf wrapped in a thin sheet of silk. A bridge is now spun to a neighboring leaf or twig and the colony begins to spread out over greater territory (fig. 4). If a second leaf is not directly accessible from the first a few venturers explore the twig by way of the leaf petiole, leaving a trail of silk along their way which guides others over the same course. Soon the stalk of another leaf is discovered and the beginnings of a web are spun about it. Emigrants from the first leaf follow in increasing numbers and soon a second is swathed in a thin web of shining new silk. Several leaves may be thus individually webbed during the first few days of the caterpillars' lives (pl. 1), but soon the spinning of a more pretentious structure is undertaken, which will inclose a group of leaves in its gossamer walls. The earlier leaves are by this time dying and turning brown and their webs are mostly deserted, though a few cater-

pillars always lag behind, but these will eventually follow the others through the series of deserted tents.

At the end of a week of feeding and working the caterpillars attain a length of about one-twelfth of an inch; the largest may be a trifle longer than this. The color of the body is pale greenish yellow, the head is black in strong contrast, on the back of the first segment there is a prominent dark Brown, shield-like, plate, and on the last segment a smaller, paler one (fig. 5). The body is sparsely covered with long hairs placed singly on small brown

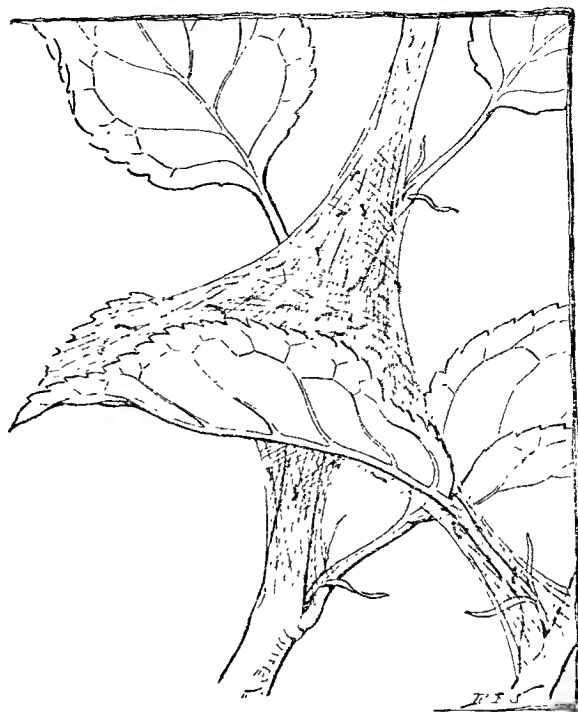


FIG. 4.—First extension of the web to neighboring twigs and leaves.

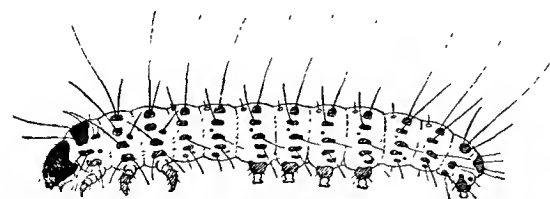


FIG. 5.—Young webworm in Stage I (natural length $\frac{1}{12}$ inch.)

knobs that give the skin a speckled appearance. The arrangement of these knobs, called tubercles, is sufficiently shown by the figure. The hairs on the back are specially long and the two median rows are very black. Caterpillars with these characters are still in the first period of their lives, which we will call Stage I. Entomologists use the word *instar* to designate the insect in itself in any stage.

After the first week some of the caterpillars will be observed to have changed in appearance and to have become abruptly larger. A search through the tents will reveal many little hairy wads which are dry, empty caterpillar skins. This means that the first molt has begun and that the caterpillars are entering Stage II. Those that have molted are about one-sixth of an inch long, twice the

length of the largest in Stage I. They are also more hairy and there is a conspicuous mixture of gray hairs with the long black ones. The general color of the skin is darker with more of an orange-yellow tone. The hairs are arranged on the same tubercles as in Stage I, but now each tubercle carries a small cluster of hairs and those on the sides just above the legs, which were bare in the first stage, have three hairs each. The head, the back plates of the first and last body segments, and the hair tubercles are dark reddish brown.

The back plate of the first segment is now divided by a pale median line. The characters of Stage II are shown by figure 6.

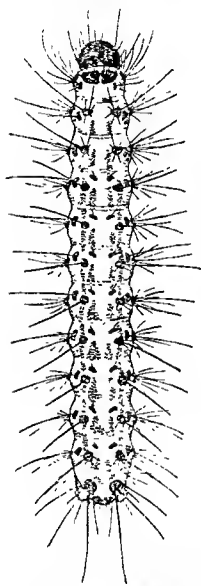


FIG. 6.—Young webworm in Stage II (natural length $\frac{1}{8}$ inch).

After their molt the caterpillars resume feeding and working with increased vigor, and more and more leaves are included in the expanding webs. The colony often splits into several sections, each constructing a home of its own. But always there are laggards that remain behind for some time in the old domiciles, generally individuals that are slow in changing their skins, presumably those that hatched latest. While most of the weavers work on the inside of the webs, many are on the outer walls where they are constantly laying on more threads, though the walls look already strong enough for all practical purposes. The tents are not hollow bags, their interiors are intricate labyrinths of rooms and galleries between sheets and strands of silk woven in all directions.

The caterpillars still feed only on the surfaces of the leaves, mostly on the upper sides, and there are as many possible dinner tables in their house as

as there are leaves inclosed within it. Yet the family prefers to eat in common, as many on one leaf as the leaf will accommodate. But instead of facing toward the center of the table, as true sociability generally requires, the diners turn their backs to one another and spread farther and farther apart as the meal progresses, till finally the table is bare except for an irregular band around the outer margin. Then the family moves on to another leaf to continue the repast, which lasts for an indefinite time. Necessarily there are no courses and no change of dishes; the same fare is served from first to last, as long as the colony remains on the same tree. The deserted banquet halls are desolate looking places, full of dead leaves and refuse, for the webworms never clean house; and a solitary diner remaining behind must make a cheerless repast on remnants amidst dirt and disorder.

By the end of two weeks from the hatching most of the caterpillars of Stage II reach a length of nearly one-fifth of an inch and have changed somewhat in appearance. The general color of the body is of a deeper tone, and there are suggestions of lengthwise stripes formed by rows of dark brown patches on the skin between the tubercles along the sides of the back, while a series of blotches on the middle of the back suggests a median dorsal stripe. Soon after this the second molt takes place and the caterpillars appear in Stage III. The general tone of the body color is now still darker than before, and the hairs are more abundant, with a greater number of the soft, pale gray ones, which gives the creatures a woolier appearance, though the large tubercles along the sides of the back bear now each 3 to 5 black hairs instead of one. The brown blotches on the back have enlarged and run together, forming a distinct, dark dorsal band. Just before each molt the caterpillar takes a premolting siesta lasting about 24 hours: and after the change it still sits around in a sleepy mood for several hours, but when this wears off it takes its place with the active ones.

The webs grow rapidly during Stage III, but the general routine of life is the same as before. Perhaps a greater number of caterpillars now work on the outside, and in this stage the writer has noticed them first feeding on the under surfaces of the leaves *through* the outer walls of the tent. This practice is more common with some colonies than with others.

About 18 days from the date of hatching the first appear in Stage IV. The longest are now three-eighths of an inch in length with hairs much longer and more numerous than before and the general appearance still woolier. The color pattern has not changed much, but the lines are darker, and the dorsal stripe is particularly conspicuous as a continuous blackish band from the dark head and thoracic plates in front to the prominent black dorsal tubercles of the twelfth segment and the back plate on the thirteenth. The under surface is pale greenish, stippled with brown; the thoracic legs are black, the abdominal legs blackish.

The web may still be a flimsy affair, straggling from leaf to leaf or from one twig to another, but Stage IV is one of the busiest periods of the caterpillars' lives. Toward the end of it they reach a length of five-twelfths of an inch and the webs attain a size that makes them begin to be noticeable objects in the trees. Individual tents may be a foot or more in diameter while deserted chambers and connecting canopies spread out over an extensive area. The size of the web depends on the size and vigor of the colony. Sometimes an

original colony splits up into two or more groups, and sometimes neighboring colonies unite, even though the members are in different stages.

Most of the time the worms are very sedate and businesslike in their actions, but sometimes as you watch a colony of caterpillars at work, all spinning and weaving as if they have not a moment to waste, suddenly, every individual rears up and violently wags its forward half, swinging from side to side with quick, short jerks. You had probably done nothing to provoke this curious demonstration, and probably if you try to make the creatures do it again by any sort of disturbance they will quietly proceed with their spinning or their eating. The writer has kept colonies indoors and many times watched them perform this wagging ceremony, but has not been able to discover a motive or in most cases any reason for it. A crowd of young caterpillars sometimes wags shortly after hatching, some colonies seldom do it at any age; one was observed for 27 days before a wagging exhibition was noted. Others wag at frequent intervals. As if at some signal the absurd performance begins and is taken up simultaneously by all members of the colony whether inside the tent or without and whether feeding or spinning. You may touch and annoy an individual caterpillar and the insignificant creature reels about, bites at your finger, and emits a drop of yellow liquid from its mouth to indicate its resentment; you may tap the nest or jar the tree without effect; but again, while all is calm and peaceful, suddenly for no apparent reason, uprears every worm and wags. One sure stimulus, however, that will always start the performance, is tobacco smoke—ever so little wafting over a tent sets all the occupants into energetic vibration. Whether the action registers disapproval or pleasure one can not say.

As the caterpillars become older an increasing number of them spend their time on the outside of the tent and feed on the lower epidermis of the leaves through the web. Some colonies that the writer studied in Indianapolis appeared to live during the fourth and fifth stages very largely on the exterior of the tents and did most of their feeding on the outside. These used the interiors principally as molting chambers, though an occasional individual even sheds its skin on the roof of the house. Colonies observed in Connecticut, however, lived almost entirely inside, except for the necessary amount of external spinning, and members were seldom seen feeding through the outer web.

It is interesting to watch the behavior of a colony during a rain. The caterpillars appear to feel the approach of a storm. During the sultry prelude, when the thunder is growling in the on-coming cloud bank, the writer has noted a complete surcease from work and has

seen caterpillars at work on outlying structures quit their spinning and gather on the top of the main web where they all stretched out motionless against the surface. Soon the big drops were coming down. The first that struck the tent only created a little commotion amongst the inhabitants, but within five minutes after the rain was coming down in earnest every webworm had moved to the under surface of the tent or to the side away from that toward which the rain was slanted. Only a few took refuge within. After a hard rainstorm the webs are wretched and bedraggled looking things, but the industrious owners proceed with the building of additions or the construction of a new house.

Sometimes a colony for some reason becomes dissatisfied with its location in a tree and decides to migrate. On such occasions the worms may move a considerable distance, going down one branch and up another, passing an abundance of foliage on the way, and generally selecting the end of a twig as a new building site. In cases of bad infestation, when a tree becomes largely or completely defoliated, the caterpillars are said to travel all over it in search of new provender or to go off to another tree. During their smaller migrations, which the writer has observed, there never appears to be any definite leadership nor any organized progression to a new camping place. A few venturers explore the twig or branch, laying a line of silk that the others eventually follow. Wherever the pioneers halt and begin the spinning of a web there the others finally accumulate and fall to work.

One writer has described the webworms as nocturnal wanderers, going forth from their homes at night to feed in the open with no protection but the darkness, returning at an early hour in the morning with full stomachs to pass the day resting inside, where they do little if any feeding. Personally I have never observed anything of this sort in connection with the webworms. Those visited at night were always either working on the web or feeding inside just as in the daytime; or, if any were away from it, they were busy weaving a new structure or an extension to the old one. For two seasons I kept colonies in my room where I lived and slept and never did the worms wander from their homes, except in the last stage when they go off but do not return. Out of doors one never sees devastated leaves in the neighborhood of the webs, while the webs are always full of them—sufficient evidence of the feeding within them. The nocturnal habits and other traits described by the present writer are so characteristic of another species, the tent caterpillar, that one is tempted to believe he did not distinguish between them in the dark.

The caterpillars of the Connecticut colony that hatched on the 15th of June began to appear in the fifth stage on July 9. In Stage

V (fig. 7) the colors are much brighter and more strongly contrasted than in the earlier stages. The black dorsal band bordered by the black tubercles along the sides of the back is now very conspicuous. The tubercles on the sides are orange. A lemon yellow band runs between the line of the black marginal tubercles of the back and that of the uppermost row on the side; while a broken white line runs between the second and third rows on the side. The ground color of the sides is greenish gray, stippled with black; the under parts are drab with black stippling; the thoracic legs and the bases of the abdominal legs are black. The hairs are now longer and more abundant

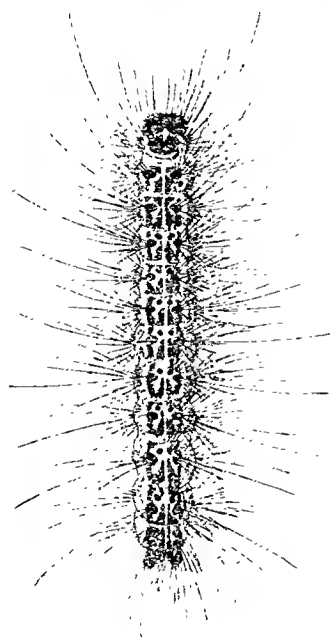


FIG. 7.—Webworm in Stage V
(natural length $\frac{3}{4}$ inch).

than ever, and the soft pale gray ones are particularly noticeable. The intensity of the colors varies much in different individuals, but the features described are characteristic of this stage and are intensified in the next. The caterpillars themselves are active, fine-looking, long-haired fellows, about three-fourths of an inch long. They run rapidly with a noticeable humping motion of the body.

The webworms seem to be creatures possessed with a spinning mania or an insatiable desire to work for work's sake. Either the weaving instinct is overdeveloped or it has survived a time when it served a greater need than at present, for the caterpillars continually elaborate the walls of their houses, although they are already fulfilling every purpose of their construction. Moreover, the webs are so soon to be deserted that such substantial building looks superfluous, and the inhabitants often move on to a new

place from a web that still contains an abundance of fresh, uneaten leaves. Yet, even when the provisions in an old tent are entirely gone, a few caterpillars will always stay with it, working away on the walls and framework as if building a memorial for all time. By night as well as by day work goes on. Late on warm nights, in the illumination of a lantern or a flash light, one may see the busy laborers swaying and twisting or dangling in mid-air in all kinds of perilous attitudes on invisible scaffoldings against the sky. Yet there are occasional periods of rest, besides those accompanying the molts, when all the

occupants of a tent are stretched out motionless, some on the outside, some within, evidently simply indulging in repose.

Whatever may be the secret motive of the webworms' industry, it does not appear to involve the idea of protection from enemies; for, whatever benefits the caterpillars may derive from their elaborate architecture, immunity from attack by other creatures is not one of them. Any bird that cares to eat hairy caterpillars could make a good meal almost any time from the outside of the webs; but the only birds known to eat webworms are cuckoos and screech owls, and certainly these do not cause any great depletion of the webworm population. Garden toads will gulp down the woolliest of caterpillars, even if they choke, but they do not climb trees. The worst enemies of insects are other insects, parasitic species that lay their eggs in the bodies of their victims. The webworms' web offers little shelter against parasites. Caterpillars on the outside are exposed to direct attack; and parasites with long, sharp ovipositors do not hesitate to enter the edifice where they stab right and left at the occupants so conveniently suspended in its meshes. Praying mantids, assassin bugs, and hunting spiders are included amongst the known predaceous enemies of webworms, but their toll on the colonies is only comparable with that of thugs and murderers in human communities. Insects in general hold their place in nature by force of numbers. Just as plants survive a multitude of destructive forces through a superabundance of seeds, so insects maintain themselves against odds by producing each season sufficient of their kind to gratify the appetites of all their enemies and still be sure of enough to propagate their species.

A few days after the webworms have shed their fourth skins they molt again and enter into the sixth and last stage of their larval lives. They have now become superb creatures an inch in length (fig. 8, and pl. 2. *C*), but they appear much longer than this on account of the great spread of the body hairs. Those on the tubercles along the sides of the back make an elegant sweep outward and upward, those on the sides curve downward, covering a width nearly equal to the length of the body. The dark band on the back is of a soft, rich velvety black, parted by a narrow, fragmentary median line of white and bordered on each side by the row of prominent black latero-dorsal tubercles. In general, the colors are deeper, the hairs longer, grayer, and woollier than in any of the preceding stages: but sometimes it is difficult to distinguish at a glance small, pale individuals of Stage VI from large, dark ones of Stage V. Measurements of the head, however, give constant differences between all stages. The webworms in Stage VI have heads two-fifths wider than those of stage V.

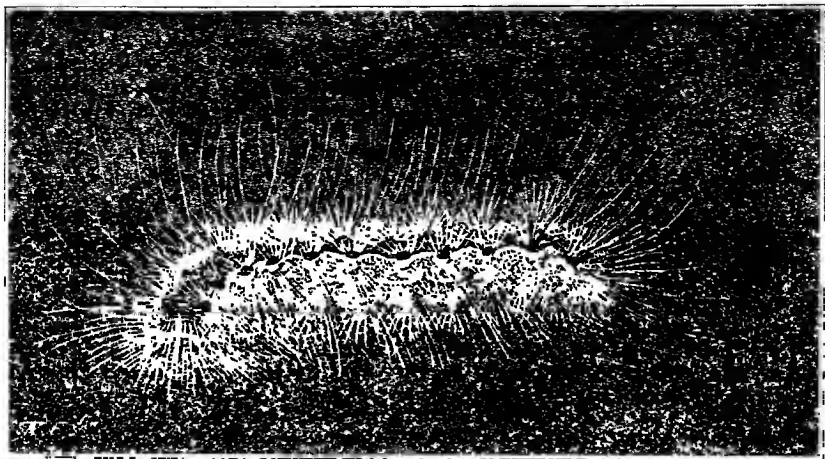


FIG. 8.—Full-grown webworm in Stage VI (natural length about 1 inch).

While the sixth stage is marked by an intensification of the physical characters of all the other stages, it is characterized by new traits

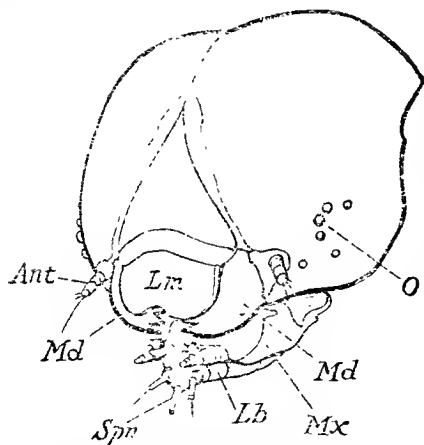


FIG. 3.—A three-quarter facial view of a webworm caterpillar's head, showing the strong, toothed jaws or mandibles (*Md*) which enable the caterpillar to bite off pieces of the leaves. The jaws are hinged to the sides of the head between the broad upper lip or labrum (*Lm*) and the thick under lip found by the united maxillae (*Mx*) and labium (*Lb*). The last carries the spine-like spinneret (*Spn*) through which the caterpillar spins its silk. On the sides of the head are the group of simple eyes or ocelli (*O*) and the short antennae (*Ant*).

of temperament. A spirit of independence now asserts itself—the caterpillars will be bound no longer by the rules and regulations that have restricted their lives thus far. They will live for a while with the smaller members of the family who have lagged behind in Stages V and IV, but they will do no work about the house or out of it, and they will totally ignore that rule of webworm etiquette which forbids the eating of the entire leaf. Instead of beginning at the center and stripping the surface outward, they now begin at the edge and devour the whole thickness, eating away all the tissue clear down to the larger veins and mid rib. Perhaps some did so in Stage V, but in general it is bad form for any but sixth stage caterpillars to feed in this manner.

Toward their smaller brothers and sisters, who are still laboring with their spinning and weaving, the big indolent fellows comport

themselves as masters toward slaves. But they soon tire of ease and luxury, and a spirit of restlessness takes hold of them. The old home no longer has attractions; the unknown world beyond is calling. So, one by one, the furry giants wander off, each choosing a route to his own liking. From ardent communists they have changed to arrogant individualists. They run rapidly with a pronounced humping movement of the back, first noticed in Stage V, a trait characteristic of the woolly bear caterpillars, to which the webworms are closely related. But the full grown webworms are not gentle like those furry creatures; they are proud and irritable and very much resent being disturbed or handled. When one of the travelers is stopped in his course by human fingers he whirls about, humps and kicks, spits out a drop of greenish-brown liquid from his mouth, and drops from the tree. During this wandering stage the webworms may be seen traveling all over trees and fences far from home, and most evidently enjoying their new freedom. They feed along the way on whatever tree or bush they happen to be upon when hunger overtakes them. Yet they do not travel like one out purely for pleasure. They go about with a nervous hurry, and are ever stopping to examine chinks, corners, and crevices as if such places held a special interest for them. This curiosity grows upon them and develops into a desire for concealment, which at last becomes paramount. In fact, the real purpose of the final wandering period in the webworm's life is the finding of a suitable shelter for its next approaching stage, that of the chrysalis or pupa.

The pupa is the stage in insects where the worm is made over into the final adult form. When the webworm caterpillar feels that its time of change is near, it selects some retreat beneath a piece of loose bark, in a corner or under any ledge of a fence, beneath rubbish, leaves, or stones lying on the ground, or it even burrows below the surface of the earth. Wherever it decides to locate, it there proceeds to spin and weave a loose cocoon of silk about itself. But, as it bends and twists at its work, its long hairs become rubbed off against the enveloping network and are enmeshed in the threads, with the result that the fabric of the finished cocoon is half silk and half wool. If the cocoon is constructed on the ground or beneath the surface, particles of earth become woven into its texture and, in this case, the denuded webworm must wear a penitential vestment worse than the traditional one of sackcloth and ashes. Most any other caterpillar would evade this hardship by secretly lining the thing with a coating of soft silk; but the webworm must have had its fill of spinning earlier in its career, for it now endures anything rather than weave more than a mere covering for itself. Some individuals avoid the spinning altogether by crawling into deserted

cocoons of other species. The cocoons of tussock moths are generally sticking about in handy places on the trees and fences, and in one of these still inhabited by the tussock pupa the writer once found a webworm stretched out beside the proper occupant, apparently waiting for its own change to take place. When the webworm's cocoon is complete it is a grayish brown, fuzzy, flimsy, oval structure, about five-eighths of an inch in length (pl. 2, D), and is often covered all over with grains of sand or bits of other surrounding material. Its walls are thin, but there is no opening left for the escape of the future moth, which must provide its own exit.

The caterpillar within the cocoon is a homely object that may well be glad of its concealment from the public. Shorn of its long hairs and shrunk to three-fourths its earlier length it now looks like nothing but a wretched worm, and bears little resemblance to the proud creature so finely dressed that but lately scorned all restraint as it wandered at large in joyous freedom. When the caterpillar's work is done it falls into a state of torpor, becoming sluggish and inert, though it is still irritable and recoils from any touch, even from any tickling on the ends of what hairs it has left; but it exhibits nothing of that active resentment to disturbance so characteristic of its active life. The small size of the cocoon compels it to lie in what looks like a most uncomfortable position with the head and tail ends bent beneath the under surface of the body. When a caterpillar in this condition is liberated from the cocoon it continues in its stupor for a few minutes and then appears to awake and become conscious that it is free again. It now slowly unbends, stretches, squirms, rolls over and finally, extending itself to nearly its normal length, walks off, gaining agility with exercise. The instinct to weave even becomes active again and some individuals are able to make what might pass for a second cocoon, though many can spin only a few threads, the one cocoon apparently having exhausted their supply of silk. But a caterpillar that is too far gone in the prepupal sleep is capable of little action beyond an occasional squirm or a sidewise roll. Such as this will soon change to the pupa wherever it may be lying.

The writer can not say just how long the webworm caterpillar remains in its dormant state, but most species spend about 24 hours in what is called the pre-pupal period. Then the skin splits over the back of the head and thorax and a hard-shelled object appears within. This is the pupa, which has already formed inside the larval skin. It has no free appendages, but by a wriggling and squirming of its flexible body it pushes its head and shoulders out of the rent, works the loosened skin down over its body, finally pushing it off completely from its tapering terminal segments and crowds

it into the rear end of the cocoon, where henceforth this last evidence of its caterpillar origin remains as a shrunken, hairy wad. The pupa sheds the larval skin in one piece, but in all the molts of the caterpillar the hard shell of the head is detached at the neck and cast off separately.

The pupa is a seedlike object about half an inch in length, having the form and structure shown in figure 10. The head end is rounded, the opposite end tapering; the partly developed legs, wings, and antennae are plainly visible but are stuck down close to the sides and under surface of the body, and are covered all over by a thin coating of varnishlike glaze. At first the pupa is pale and soft and is capable of considerable wriggling movement. The head, thorax and wings are greenish, the abdomen dull yellowish. After about 12 hours, however, the skin hardens to a brittle shell, the colors change to a uniform dark reddish brown (pl. 2, *E*), and the power of motion is almost

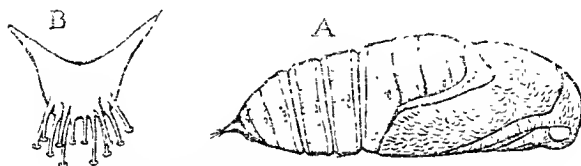


FIG. 10.—A, Pupa of webworm (natural size $\frac{1}{2}$ inch long); B, spines at end of body (more enlarged).

lost. A hard-shelled pupa like this is called a *chrysalis*. The three intersegmental lines between the fourth, fifth, sixth, and seventh segments of the abdomen (fig. 9) form deep grooves around the body which retain a flexibility that allows the creature to twist the rear end of the body a little, the only form of exercise it can now take. The fore parts are sculptured all over with small irregular rugosities, but the metathorax and the abdomen are closely punctured with shallow pits, except the sides of the three intersegmental grooves which are smooth and polished. The last segment ends in a flat tongue which bears a fringe of slender spines, each ending in a flat, cupped disk.

The cocoon-making period of the webworms extends from the middle of July to the second week of August, depending on how early the eggs were laid and hatched in the spring, on the latitude, and on the climate of any particular season. Exact dates for the events of an insect's life are of interest or value only in connection with local conditions and must be determined separately for each locality where the species is studied. After a week or more of confinement in its cell, straight-jacketed in the pupal skin, the creature that was formerly a web-worm is set free again by nature's invisible warden. The shell-like skin of the pupa opens along two lines, one on the mid line of the back of the first two body segments, the other around the back of the head and down the rear edges of the antennae. The second

split cuts out a long shield-shaped piece in the lower side of the pupal shell, which drops down and allows the prisoner, already become a moth, to emerge as far as the narrow limits of the cocoon will permit. Some caterpillars have the foresight to leave a partly open door at the end of the cocoon for the convenience of the moth, but the webworm does not concern itself about any such provision for its future. Yet the moth escapes. Cocoons from which the moths have emerged have a round hole at one end with the edges flaring outward. It is presumed that the moth exudes a liquid from its mouth that softens the wall of the cocoon sufficiently for it to push through. The crumpled wings then expand, the feeble legs gain strength and, when night comes, the moth flies back to freedom in the trees.

But what a transformation the creature has undergone since its larval days. The moth is the perfect insect and is like its parents, but the caterpillar has departed far from its ancestral line. By letting its appetite get away with it, it degenerated into a worm, and nature had to shut it up in the pupal shell to reform it and make it over again into a moth. The cocoons are often to be found amidst damp, dark, moldy surroundings under rubbish on the ground, and the gentle snow-white moths, with their large, soft black eyes, emerging from such incongruous environments seem to signify that the caterpillar's sins have been fully expiated. The purified creature will henceforth eat no more. Perhaps a dewdrop will slake its thirst, but solid food will never pass its lips, nor will it be tempted, for it has no jaws (fig. 11) and probably no appetite. Its body contains a supply of predigested nourishment stored up by the caterpillar sufficient for the rest of its life. The business of the moth is to produce the eggs that will generate the succeeding brood of caterpillars.

The moths from the spring generation of caterpillars lay their eggs during the latter part of July and the first half of August, placing them on the undersides of leaves as did their parents in the spring before them. A second brood of caterpillars issues in a shorter length of time than did those produced by the spring eggs, because the weather is now warmer and hastens the incubation, 7 to 10 days being usually sufficient at this season, whereas in the spring eggs remained unhatched for as long as 15 days. The young webworms proceed at once with the construction of another set of tents which are finished by late summer or by early fall. Then the full-grown caterpillars are again to be seen wandering at large, till they in turn spin their cocoons and change to pupae. The fall pupae, however, are destined to remain within the cocoons until the following spring, for the moths that emerge from them are those that will start the webworm life all over again next year.

The webs of the two generations of caterpillars become so numerous and so conspicuous in the trees by fall that probably for this reason

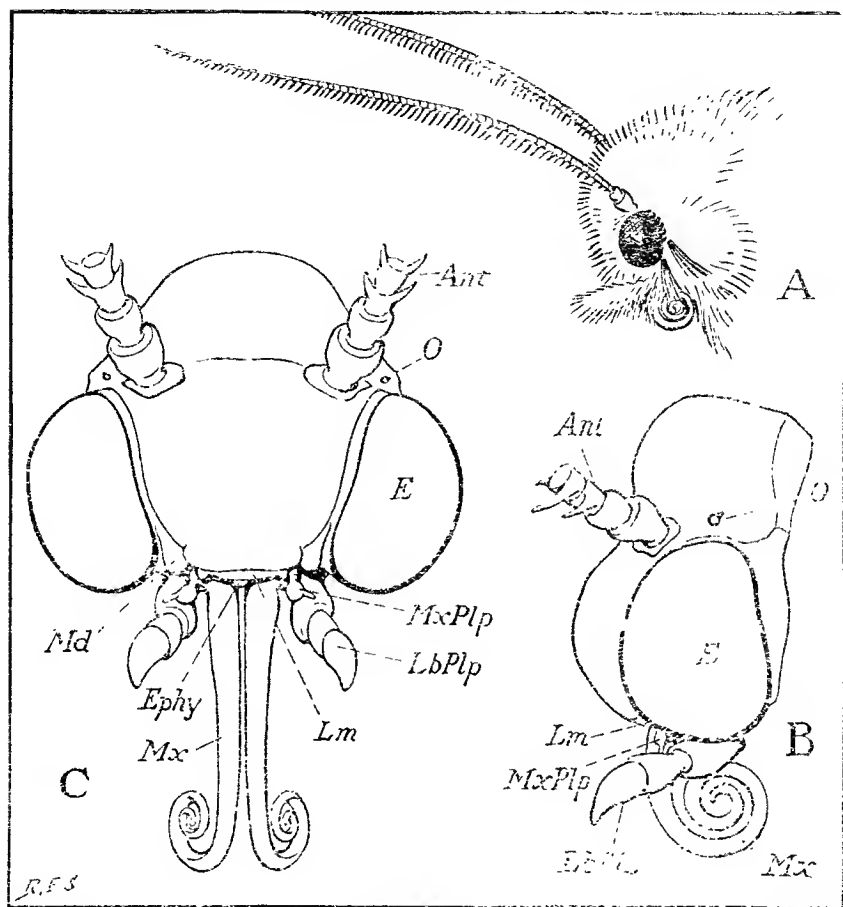


FIG. 11.—The head of a webworm moth. A is a side view showing the proboscis coiled beneath and the antennae projecting from above the eyes; B is the same, more enlarged, with the fur removed and only the base of one antenna (Ant) shown; C is a facial view showing the large compound eyes (E) on the sides of the head and the small eyes (O) above them. At the lower edge of the face, in front of the mouth, is the narrow upper lip or labrum (Lm). Behind the mouth is a weak lower lip, not shown, which supports a pair of jointed appendages, the labial palpi (LbPlp). At the sides of the mouth are two long strap-like appendages (Mx) which, in life, are united along their inner hollowed surfaces and form a tube, the proboscis, through which the moth sucks up water or nectar. When not in use the proboscis is coiled beneath the head as in figures A and B. The parts of the proboscis represent a pair of jaws in other insects, and are united with the lower lip in the caterpillar (fig. 9, Mx and Lb). Each carries a small palpus at its base in the moth (MxPlp). The biting jaws of the caterpillar (fig. 9, Md) are reduced to small knobs (Md) in the moth, which can not eat solid food. A small point, called the epipharynx (Ephy), projects beneath the upper lip (Lm).

the species has been named the fall webworm (*Hyphantria cunea* of entomologists), which name distinguishes it from several other kinds of webworms. The webs somewhat resemble the homes of the tent

caterpillars; but the tents of this species do not inclose leaves and are used only for shelter, the occupants going out in bands to forage on the leaves of the trees, returning home to rest after each meal. In some parts of the country, particularly in New England, the fall webworm is commonly known as the "bagworm," but it is improperly so called because this name belongs to another caterpillar, one more abundant farther south and more properly deserving of the name since it encases its body in a close-fitting bag.

The fall webworm belongs to the family Arctiidae, which includes also such well known caterpillars as the brown and yellow woolly bears and the hedgehog caterpillar. The last is that popular weather prophet who is supposed to have his brown and black colors proportioned each fall according to the weather prospects of the coming winter. Most of the Arctiid caterpillars are hairy or woolly and have the hairs grouped on tubercles of the skin. They run with that characteristic humping motion noted especially in the later stages of the webworms. The moths are of medium size but most of them have strikingly beautiful colors, the wings being white, yellow, brown or red, and spotted or banded in a great variety of patterns. For this reason they have been given the general name of tiger moths. Some of them, however, are of plain colors. The moths of the fall webworms are usually pure white, though some have the front wings covered with small brown or blackish spots and the abdomen brownish above (fig. 11), while an occasional individual has a few spots on the hind wings. The spotted ones are usually males, though some females also are spotted. The back of the thorax and the head are clothed in long soft fur, the large black eyes stand out prominently on the sides of the face, while below each eye are two small tufts of blackish hairs. The antennae are usually white above, dark brown beneath, with the brown encroaching on the sides of the segments and producing a spotted effect, but often the upper surface is brown also though the fringe may be white. The bases of the front legs and parts of the middle legs are pale sulphur yellow. The tibiae and feet usually are blackish on their front edges except at the ends of the joints, which gives them the appearance of being ringed with white. The wings expand from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches and when closed the body and wings are five to seven eighths of an inch long.

The fall webworm ranges all over the eastern part of the United States from the Atlantic coast to the Rocky Mountains, and also lives in parts of California. It feeds on a great variety of deciduous trees, 120 species being listed in its known diet as given in Bulletin 10 of the U. S. Bureau of Entomology. It is particularly a pest in orchards and on city shade trees. Trees kept sprayed with arsenicals are of course freed from webworms along with other leaf-feeding

ing species. Ordinarily webs can be easily removed from small trees by cutting off the supporting twigs or by burning with a kerosene torch.

The webworms that live in Canada, in New York State, and in New England north of the middle of Connecticut are said by some entomologists to be different from the common *Hyphantria cunea*, being darker in color and having reddish-brown instead of grayish hairs in the last stage. These have but one generation in a year and the caterpillars spin larger webs. The moths can not be distinguished from the pure white forms of *cunea*, but none of them ever have any spots on the wings. This northern form is distinguished in name as *Hyphantria testator*. When the moths of the two species are caged together the males and females of each mate freely amongst their own kind, but they will not intermarry. These points have all been described by H. H. Lyman in the thirty-second report of the Entomological Society of Ontario for 1901.

It is too bad that we ourselves have reached a mental state so far above the other creatures, because it cuts us off from all communication with them. We are hopelessly above any intimate understanding of the mind of a caterpillar, and as a consequence we are loath to credit it with having any mind at all. Most people do not even know that a caterpillar has a nervous system. Yet it has a brain, a long nerve cord, and nerves that branch to all its parts and regulate its actions the same as ours are governed. But the acts of the caterpillar are attributed by us to what we call instinct, a word that we can pronounce better than we can define.

Yet, even if we must regard insects as mere automata, unwittingly acting in response to internal stimuli of some sort, the successive adjustment of these impulses to the creature's varying needs is something still beyond our powers of comprehension. A brief outline of the webworm's life will illustrate how all its acts are primed to follow one another in unvarying sequence and to be always operative at the proper time and place. The nervous mechanism may be likened to those bombs of modern warfare which are timed to go off precisely when they reach the mark at which the gunner aims them. With the caterpillar every impulse is prearranged, predestined in the egg, for each individual goes through all the acts of its life in the same rotation. Nature has laid down a curriculum which all that live must follow. In our present state of knowledge we do not know what may be the nature of the commands that drive the creatures on, nor how they are communicated, but an analysis of what is involved would be something like this: The controlling force is located in the central nervous system and is implanted there by heredity, for insects learn nothing by education and serve no appren-

ticeship in their trades. Therefore, in the egg something is registered on the substance of the future nervous tissue that, at a certain period in the future caterpillar's life, gives the command to work, to spin and weave a house of silk. Then, on this same or other nerve tissue, another command is registered, to be effective only after the other has been executed, which says, "cease work and take life easy." A third says, "travel." A fourth in turn says, "find some secluded place, regardless of the nature of the surroundings, and there surround yourself completely with a case of silk." After this the purely vegetative forces become predominant and changes follow in which regulated movements have no part. The change to the pupal stage and the final transformation to the moth are all physiological processes of growth; but even here the shedding by the pupa of the larval skin and the escape from the cocoon by the moth are acts of coordinated instinct. The moths themselves are bound by few rules of conduct. When the instincts to mate and to lay eggs on the leaves of trees have been fulfilled, their duties and their lives are ended.

Though we may have no unquestioned evidence that the power of reason is possessed by any insect, still, can we conceive that a mere mass of organized matter can do all the things that a webworm does, and yet have nothing in common with ourselves? Can the caterpillars have appetites, a sense of touch, fear of danger, and show resentment at an interference with their natural rights without some consciousness at least of their own existence? Does the worm turn with no more emotion than a piece of rubber? And, can we really believe it even if we think so?



FIG. 12.—Moths of the fall webworm, a pure white and a spotted individual (a little larger than natural size).

COLLECTING INSECTS ON MOUNT RAINIER.

By A. L. MELANDER,

Professor of Entomology, the State College of Washington.

[With 9 plates.]

Monarch of mountains is Rainier. But a few hours ride by train or auto southeastward from Tacoma, this massive peak rises to a height of 14,400 feet. Other mountains may be higher but none is as stupendous as the ice-covered dome of Rainier, pushing heavenward almost from sea level. The Indians revered the mountain as their god. Their white successors have created a national park about it, and modern roads and ways of conveyance now place the gardens of Paradise within easy access of all.

To the naturalist the broad slopes of the mountain are replete with more than ordinary interest. In a couple of hours it is possible to ascend through life zones almost duplicating those requiring a journey of thousands of miles to the north to explore. The dense tall forests at the foot of the mountain give way to open woods of stunted trees as the higher altitudes are reached, and these in turn to alpine grassy meadows, to gorgeous flower gardens, then to barren stone fields and to perpetual snow and ice.

As the vegetation changes at successive elevations, so different insect forms are encountered. The wealth of unusual species and often the abundance of individuals of bizarre forms make insect collecting on the slopes of Rainier a most exciting experience for the entomologist. The vastness of the mountain, bespeaking a great circumference to the various encircling life zones, has permitted extensive breeding grounds and lessened the chance of extinction of stranded forms left on its slopes at the conclusion of the great ice age. Thus it is that Rainier, more than any other mountain in the United States, shows an unusual number of species the counterparts of which live far to the north.

One of the main advantages of Rainier is its accessibility to the tourist. Most visitors enter the national park at the southwest or Nisqually entrance, coming over the roads from Tacoma. Those bringing camp outfits are permitted to tent at certain designated sta-

tions, the most important of which are Longmire's Springs and Paradise Park, at both of which food supplies can be purchased from the stores. Elaborate hotels and less pretentious tent houses are also maintained at these two stations for the convenience of the unencumbered traveler.

Between the park entrance and Longmire the road winds through a dense forest of huge evergreen trees, the Douglas firs rivaling the giant trees of California in height. This forest is luxuriantly carpeted with shrubbery so as to be almost impenetrable at times. Large-leaved spiny devil's clubs, vine maples, alders, salmon berries, and spiræas help fill in the underbrush. Insect collecting in this darkened zone of from 2,000 to 3,000 feet elevation is mainly characterized, as elsewhere in the forests flanking the Cascade Mountains, by the abundance of small flying forms in early summer and the paucity of specimens after midsummer.

Above Longmire in general the forest opens, the trees are smaller, and different species enter to take the place of the larger trees found mainly below. The underbrush is less dense, mainly ericaceous, and in the burns along the ridges consists largely of fireweed and huckleberry. In the damper stretches microdiptera abound as in the lower woods. A chance dropping of bear dung entices swarms of coprophilous borborids. Tiny Rhamphomyias weave their interminable dance over the pools and rills, the silvery females hovering close to the surface of the water, the more venturesome black males going forth to capture the midges used as a mating offering. Over the purple flowers of the pentstemons a cloud of midget *Anthalias* zigzag up and down. Mosquitoes are a plague in the early summer. Bloodsucking *Symphoromyias*, called "the bad biter," follow the traveler and vie with the smaller buffalo-gnats, which have emerged from the mountain streams, in being a torment.

In the open there is less dearth of flowers and the insect fauna correspondingly changes. *Syrphus* flies, bumblebees, wasps, butterflies, and longhorn beetles are more abundant, but to the collector who is familiar with forest insects, so far there is nothing distinctive of the greatest mountain. At an elevation of about 5,000 feet, reached all the way by a road so evenly graded that automobiles ascend on high gear, suddenly a vista of an alpine flower park opens beyond a clump of scrubby trees. The effect of the first view is startling. In profusion of species, in infinite beauty of color, in the expanse of natural beds of flowers, the gardens of Rainier are wonderful beyond description. The verdict of mountaineers is that they surpass those of any other alpine region of the world. Reds, blues, yellows, purples, and white are commingled in luxuriant growth. It seems a sacrilege to wade knee-deep through

the flowers, but the swarms of mountain insects are too great a provocation for an entomologist to resist.

In alpine regions the growing season is short. The gardens of Paradise Park are covered by many, many feet of winter snow which does not melt completely away until late in August. Beds of avalanche lily and of the large western anemone follow the retreating snowline, even pushing out their flowers through the disappearing crust. In a few weeks, or a few days even, the flowers must make their appeal for insect pollinators in order to mature seeds by the time of autumn snowfall. The struggle for existence is thus especially keen and the competing plants develop color, perfume, and nectar to the utmost. There are also physiological reasons why mountain gardens are so marvellously attractive to insects. The intensely sunny days alternating with the cold nights increase the production and condition the storage of sugars, and also influence the development of color.

Flowers in their phyletic making are illustrated by the castillejas, or Indian paintbrush. The floral parts of these plants are inconspicuous at the top of an erect stalk, but are advertised by whorls of compacted red leaves, that function like specialized corollas. Castillejas elsewhere are usually a salmon yellow, but on Mount Rainer several species approach a true scarlet.

Strangely enough, it is not the brightest-hued flowers that are visited by the most insects. Perhaps their colors are to compensate for other lack of appeal. The brilliant outstanding red paintbrushes, the beds of solid blue lupines, or the mats of pink heather are not the best places for the entomologist interested in general collecting to seek. Instead, it is the white heads of the ill-smelling valerian over which insects swarm. Bumblebees of many coat patterns, the large syrphus fly, *Sericomyia chalcopyga* (pl. 9, fig. 1), first described from Alaska, ichneumons, sawflies, butterflies, tachinids, the broad-shouldered beetle, *Pachyta* (pl. 8, fig. 12), and many species of syrphus flies attend these flowers in unbelievable numbers. Other flowers characteristic of the alpine gardens which are frequented by flying insects are the broad-leaved hellebore or veratrum, the nodding heads of mountain dock, the white avalanche lily or deerstongue, and the large western anemone.

The ridges above the alpine gardens teem with insects whenever the sun shines. A favorite promenade of a half-mile to the north of Paradise Inn is the climb to Alta Vista. This ridge has proved to be one of the best of collecting fields for insects. The copses of stunted alpine hemlock and subalpine fir on its slopes have produced several undescribed species of dance-flies. Now and then among the shadowy trees can be seen a conspicuous steel-blue horn-

tail wasp (pl. 8, fig. 9), seeking to deposit its eggs beneath the bark of one of the firs. Here, also, the prize of the mountain, *Pocota grandis*, a large bumblebeelike syrphid (pl. 9, fig. 3), may alight on the panicles of mountain ash or rosy spiræa.

In the open spaces at the crest of the ridge a group of insects disport themselves in the sun. A bee fly of the genus *Anthrax* (pl. 8, fig. 3) flattens itself against the rocks to absorb to itself whatever heat may radiate, the silver base of its wings reflecting the sun like a mirror. Another bee fly lacks the epaulets, but is equally conspicuous by its dense coat of crimson hairs. A beautiful but rather rare western fly, *Arctophila flagrans* (pl. 8, fig. 1), which ranges from Alaska to New Mexico, also frequents this ridge. Here in a few minutes we have seen more specimens than in years of summer mountain collecting elsewhere. Two variations of this species occur, one covered with uniformly golden silky hairs, the other with bright red hairs over the abdomen. It is interesting to notice how many of the western flies that mimic bumblebees have a red abdomen, like the common western species of these bees. As would be expected from the presence of the red-tailed mimics, the red-bellied bumblebees also occur on Mount Rainier in abundance. A sister species to *Arctophila flagrans* was described in 1908 from British Columbia under the name of *Arctophila Harveyi* (pl. 8, fig. 2). This species is regarded by collectors as one of the most desirable of the popular family Syrphidæ. It resembles the white-tailed western bumblebee, *Bombus occidentalis*, in coloration, and is closely akin to the European type of this northern genus, *A. bombiformis*. Needless to say the discovery of this species on Alta Vista was a cause for rejoicing. This fly was not so fond of basking as *A. flagrans*, but hovered shyly at the edge of a copse and seemed to show a predilection to settle among the twisted flowers of the curious lousewort, *Pedicularis racemosa*.

It is characteristic of mountain diptera that many species are mimics, closely resembling wasps, yellow jackets, and bumblebees. This impression may be due to the predominance of the family Syrphidæ which contains many mimetic forms. On Rainier a dearth of yellow jackets is accompanied by a corresponding decrease in hornetlike forms, while the unusual abundance of bumblebees is reflected in the prevalence of fuzzy-hairy flies. Nowhere in our experience have we encountered more bumblebees than in these flower gardens.

Even the dead and bared tree trunks produced their quota of interesting species. On Alta Vista a beautiful species of the slender black bee fly, *Eclimys* (pl. 8, fig. 6) was encountered day after day on the weathered "ghost trees." A tiny fly which proves to be an undescribed genus of the Milichiinæ was also discovered peering and

probing into cracks and seams in these trees. Shining black carpenter ants likewise appropriate the dead trees for their nidifications. Several species of robber flies, one with beautifully pictured wings and yellow-plumed abdomen (pl. 8, fig. 8), use the tree trunks as a vantage post from which to pounce down on an abundant but luckless prey.

One of the big buzzing flies, a cutworm parasite generally known as *Echinomyia algens* (pl. 8, fig. 4), is a regular visitor to Alta Vista, coming up in numbers to disport itself in the warm sunshine after its tour among the flowers below. This is a shining black bristly species, one of the most active of all, but since its wings are small as compared with its bulky body, it must vibrate them the harder to get into flight. Hence it is rare to find a specimen on the ridge not having its wings frayed and torn. Like the flowers that hurry through their short season, the flies are energized by the actinic sun rays, and thus they are capable of more rapid movements than are the insects at tidewater level or those of the somber cool forests. It is the pursuit of elusive insects like these that gives to mountain collecting the exercise of a tennis game coupled with the zest of capture that comes with angling and hunting. It is fortunate for the entomologist that national park regulations are not construed to forbid insect collecting, since they do prohibit the general public from picking flowers and killing game.

When the sun shines on the alpine parks it is hot. Even on the snow fields, where it is freezing under foot, mountain sunburn is a serious and not to be belittled affliction. The absence of the bottom mile of air removes a potent filter of light and heat and the sunshine is correspondingly intensified. The photographer must make allowance for the greater chemical energy of the sunshine, just as the flowers and insects have adjusted themselves to their alpine surroundings. But the sun may not shine every day. The mountain visitor must not come with the expectation that every summer day will be filled with the glory of sight-seeing, for sometimes the parks are enveloped in clouds and sometimes it rains. The vastness of the icy dome, said to be more extensive than the whole glacier system of the Alps, coupled with the rarified atmosphere, causes cloud formation and on the slightest provocation the precipitation of rain. In its way it is interesting to sojourn among the clouds, thus to learn that they are not fleecy, but depressingly damp and cold. It is startling to watch the fantastic shapes of mist arise from the clear air, that in a few moments may obliterate all view of the mountain and drive into hiding every form of insect life. But when day follows day of rainy weather the entomologist is not so keen for the "Camp of the Clouds." Fortunately he is at liberty to move to one of the

lower stations where clouds and rain are not excessive. The guides inform visitors that Rainier is accented on the first syllable, and sometimes the visitor is inclined to reply that the mountain is rainier than other places.

In the course of his rambles the entomologist will take one of the trails to the east leading up the valley of the Paradise River, past the marvelous Sluiskin Falls, to Mazama Ridge. Sluiskin Falls is named after the Indian guide who, in 1870, conducted the first white explorers as far as this point and refused to desecrate the mountain by advancing beyond the timberline on Mazama Ridge. The lower part of this trip leads through grassy meadows furrowed by rills of ice-cold water which course from the snow fields above. These rills are the haunts of various cascade-loving insects. Several species of rare craneflies and clinocerans and three undescribed genera of empidine flies have been taken along the banks of these rivulets. Two of the new genera were found in abundance during the middle of August in 1917. At that time the writer was called away to another part of the State and on returning a week later found the rills dry and the flies gone. A visit to the same fields the past summer failed to disclose a single specimen of the sought-for insects. In common with the majority of mountain insects, the appearance of these empids is ephemeral. One can not leisurely select his convenience to make their acquaintance, but must be guided by their time for emergence. The soil on the mountain sides is shallow and incapable of storing moisture. While the snow is going off the sod is boggy and marsh-inhabiting insects abound. A week later might witness a complete transformation. The ground has become parched, lilies have progressed from flower to seed, and the former insects have disappeared, their places being taken by a new set of autumnal species, the tiger beetles (pl. 8, fig. 5) being among the few to remain over.

The slopes near Sluiskin are steep in the extreme, but are luxuriantly overgrown with hellebore and other more brilliant flowers, and crowned by a fringe of mountain ash trees. The crest is Mazama Ridge and marks the highest extension of the forest trees. Here at an elevation of about 6,300 feet are to be found distorted, prostrate dwarfs of the trees that grow so nobly below, now but a few feet in height, yet possibly centuries old. Submerged under snow all but a few weeks of the year and growing out of the soil-bare rocks, it is an inhospitable environment they find. No wonder that they are stunted. Sharply marked are the last groups of trees, that have encroached on the glaciers to the limits of possible endurance, and beyond them stretch miles of ice, broken only where ridges or jumbles of volcanic rock jut through.

Mazama Ridge, like the lower ridge at Alta Vista, halts many insects in their upward flight. At the very edge of the snow field, the patches of bare volcanic sand are sufficiently warmed by the sun to hold a little gathering of passers-by. Bee flies, "fleshflies," tiger beetles, several species of large horseflies, and dainty little butterflies appropriate the sands as basking ground or dart back and forth in the vicinity. One of the most beautiful of syrphus flies, *Caliprobola pulcher* by name (pl. 8, fig. 7), is at home here, its metallic bronze-green body reflecting the sunshine thus to catch the collector's eye and to arouse his cupidity. It is interesting to note the proximity of strictly vernal forms and those of high summer at the edge of the snow field. Nowhere at low elevations would it be possible to find sawflies, mosquitoes, crane flies, and springtime empids cohabiting with summer forms like robberflies, tachinids, bee flies, and long-horn beetles.

A short walk beyond the ridge, over the Paradise Glacier, brings one to the edge overlooking the deep valley of the Cowlitz. Here the slope is overgrown by the Indian basket grass which is the most conspicuous of the alpine flowers. This plant is a species of lily, with a hundred or so small creamy flowers crowning a tall, erect stalk set in a dense mat of radiating narrow leaves. The flowers of the basket grass are attractive to many insects but particularly to the huge syrphid fly, *Pocota grandis* (pl. 9, fig. 3). It has been our good fortune to see hundreds of these remarkable insects darting from flower cluster to flower cluster, and even to catch them by the camera as well as by the net.

All of the insects that congregate on the ridges are not admired by tourists, however, for mosquitoes likewise gather in disconcerting numbers whenever the wind is not stirring. Naturally the marshy flanks of the mountain afford excellent breeding places for mosquitoes, and at times these insects are decidedly in evidence, necessitating the wearing of a veil or the application of a perfumed oily repellent for comfort. Fortunately, from our experience, the species are strictly diurnal, so that when the cold air currents descend from the ice dome at night mosquitoes do not trouble the camper's sleep. Whenever one of the periodical storms sweeps over the mountain, the frail mosquitoes are blown away, where we do not know or care, but for days afterward there is a respite from their attacks, until a new invasion emerges from the pools or comes up from below.

Although conspicuous plant life ceases at the timber line, insects occur still higher. Some of the species are indigenous, like the wingless grasshoppers (pl. 9, fig. 2) and lubber crickets (pl. 9, fig. 6) of the punice fields. It seems remarkable that a plant-eating insect like the dectiine cricket could occur so abundantly in a spot so bar-

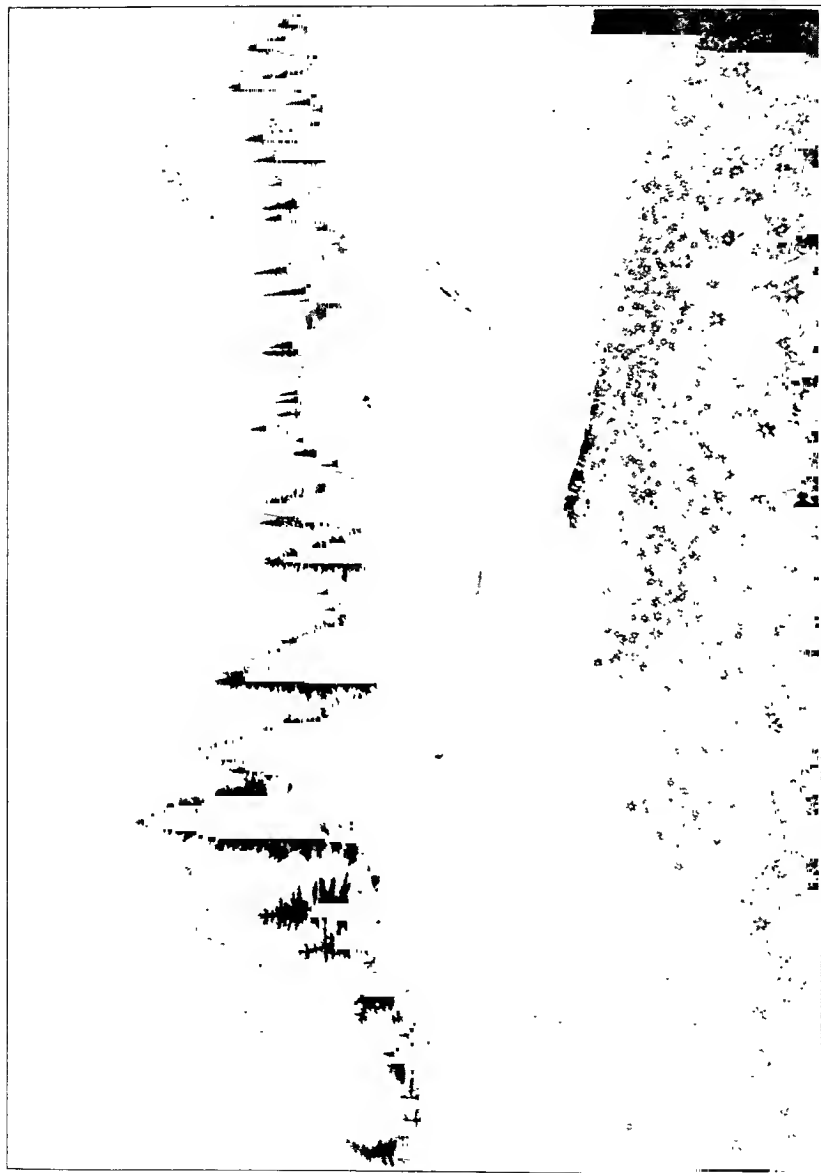
ren. What they can find for subsistence is probably a greater problem for them than for us. Most of the species of insects of the higher altitudes, however, are ascending migrants that have lost their way. Ichneumon flies, flying ants, syrphids, and butterflies, impelled by the remarkable instinct to fly upwards, are overcome by the cold and drop to perish on the ice. It is no trick to do a good day's collecting by picking up these wayfarers when one is trudging over the icy wastes. Even at the very summit $2\frac{1}{2}$ miles above the base of the mountain, the mountaineer guides report the usual occurrence of butterflies and syrphids.

The plants of Mount Rainier are known comparatively well, for many botanists have explored its slopes. Piper enumerates over 300 species of flowers. The birds and mammals are being studied by the United States Biological Survey, but the species of higher mammals are decidedly limited in number, so there is a prospect of this task being completed within a reasonable time. As far as we know no one has undertaken a methodical study of the many species of insects found on Rainier's slopes. Desultory collecting of insects has been done from time to time by Aldrich, Dyar, Kincaid, Piper, and undoubtedly others, but the rich insect fauna of Rainier still remains practically untouched and unknown, even though the alpine fauna of no other mountain is so inviting and so accessible. The relationship of the insect fauna of Rainier to that of the neighboring ice-mantled peaks, Baker to the north, and Adams, Hood, and St. Helens to the south, the extent of arctic components of its fauna, the zonal distribution of its insects, and the correlation between the insects and the distinctive flora are problems for the future.

Much has been said and much has been written about the majesty of this king of mountains and the wonder of its crown of alpine flowers. Of these accounts the most expressive is the following brief summary of John Muir's visit.

Of all the fire-mountains, which, like beacons, once blazed along the Pacific coast, Mount Rainier is the noblest in form, has the most interesting forest cover, and, with perhaps the exception of Shasta, is the highest and most flowery. Its massive white dome rises out of the forests, like a world by itself, to a height of 14,000 to 15,000 feet. The forests reach to a height of a little over 6,000 feet, and above the forests there is a zone of the loveliest flowers, 50 miles in circuit and nearly 2 miles wide, so closely planted and luxuriant that it seems as if nature, glad to make an open space between woods so dense and ice so deep, were economizing the precious ground, and trying to see how many of her darlings she can get together in one mountain wreath—daisies, anemones, columbines, erythroniums, larkspurs, etc., among which we wade knee-deep and waist-deep, the bright corollas in myriads touching petal to petal. Altogether this is the richest subalpine garden I have ever found, a perfect flower elysium.

The purpose of this paper is to urge others to share the joys of a visit to this grandest of our national playgrounds.

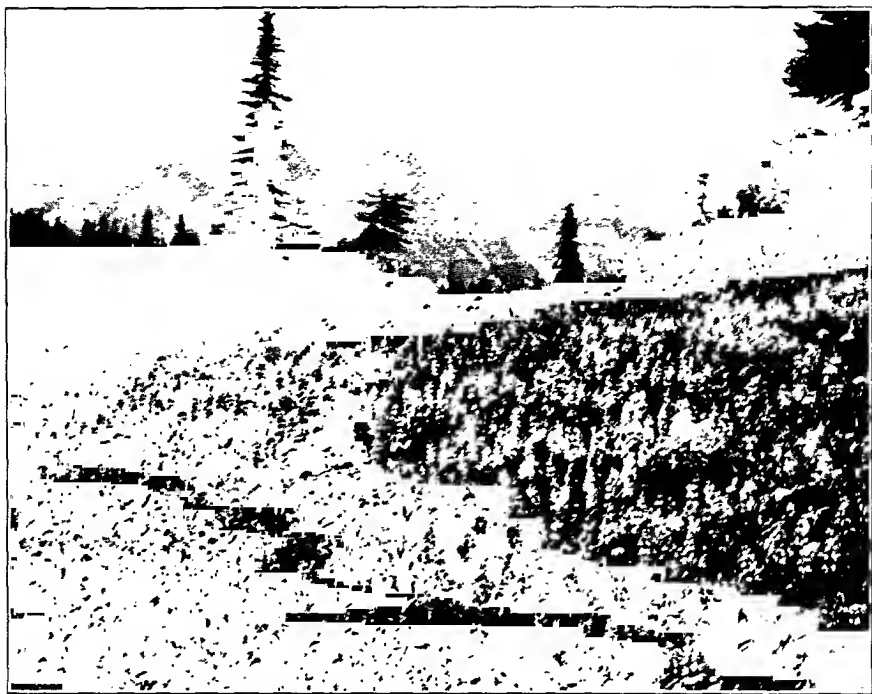


VIEW OF MOUNTAIN DOME FROM PARADISE VALLEY.

Beds of avalanche lilies encircled by alpine firs characterize the natural parks just below the snow line.



MOUNT RAINIER AS SEEN FROM THE WEST SLOPE OF ALTA VISTA.
Fire-killed ghost trees, silvered by exposure, remind us how quickly the growth of centuries can be destroyed



A. VIEW OF TATOOSH RANGE, WHICH HEMS IN PARADISE PARK TO THE SOUTH.

Red, white, and blue are the principal floral colors in the National Park.



B. PARADISE VALLEY JUST BELOW THE PUBLIC CAMP.

Nothing heads of mountain dock beat time to the changing zephyrs.



A. FIELD OF BASKET GRASS (*XEROPHYLLUM TEXANUM*). THE LARGE FLY *POCOTA* HOVERS OVER THE FLOWERS.



B. FIRE WEED (*EPILOBIUM ANGUSTIFOLIUM*) IN THE OLD BURN NEAR NARADA FALLS.



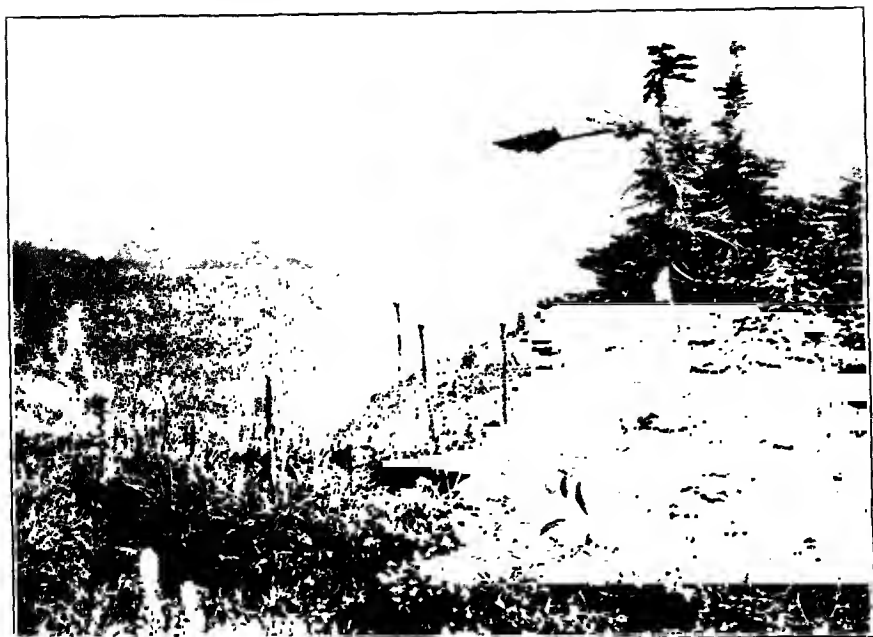
C. A CLOSE-UP VIEW OF AVALANCHE LILY AND PAINT BRUSH. NOTICE THE FLY *SERICOMYSIA* VISITING THE LILY.



A. A BIT OF MOUNTAIN GARDEN IN PARADISE PARK SHOWING MOUNTAIN DOCK (*Polygonum bistorta*), LUPINE (*Lupinus subalpinus*), WILD PARSNIP (*Ligusticum purpureum*), VALERIAN (*Valeriana sitchensis*), AND SEED PODS OF WESTERN ANEMONE (*Pulsatilla occidentalis*).



B. A COMPACTED AND VARIEGATED GARDEN ON THE WEST SLOPE OF ALTA VISTA. FLOWERS TOUCH PETAL TO PETAL.



A. OVERLOOKING THE STEVENS VALLEY. MOUNTAIN HEMLOCK IS A STately TREE ON THE LOWER SLOPES BUT IS STUNTED ON THE RIDGES.



B. PARADISE RIVER BELOW SLUISKIN FALLS.

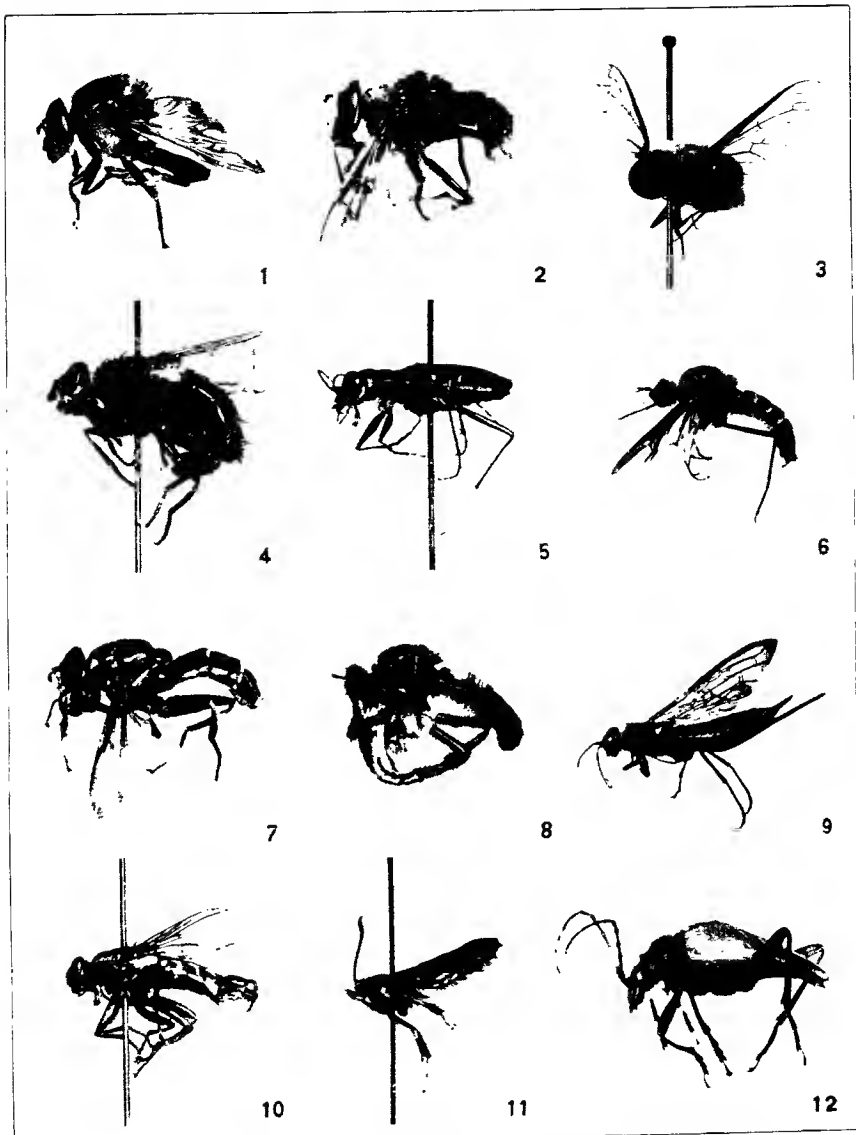
At the conclusion of the brief summer the characteristic flower is the mountain aster.



A. LOOKING NORTH FROM 9,000 FEET ELEVATION. THE SUMMIT IS 5 MILES DISTANT. DESOLATE, INHOSPITABLE IN THE EXTREME, ARE THE PUMICE FIELDS ABOVE TIMBER LINE.

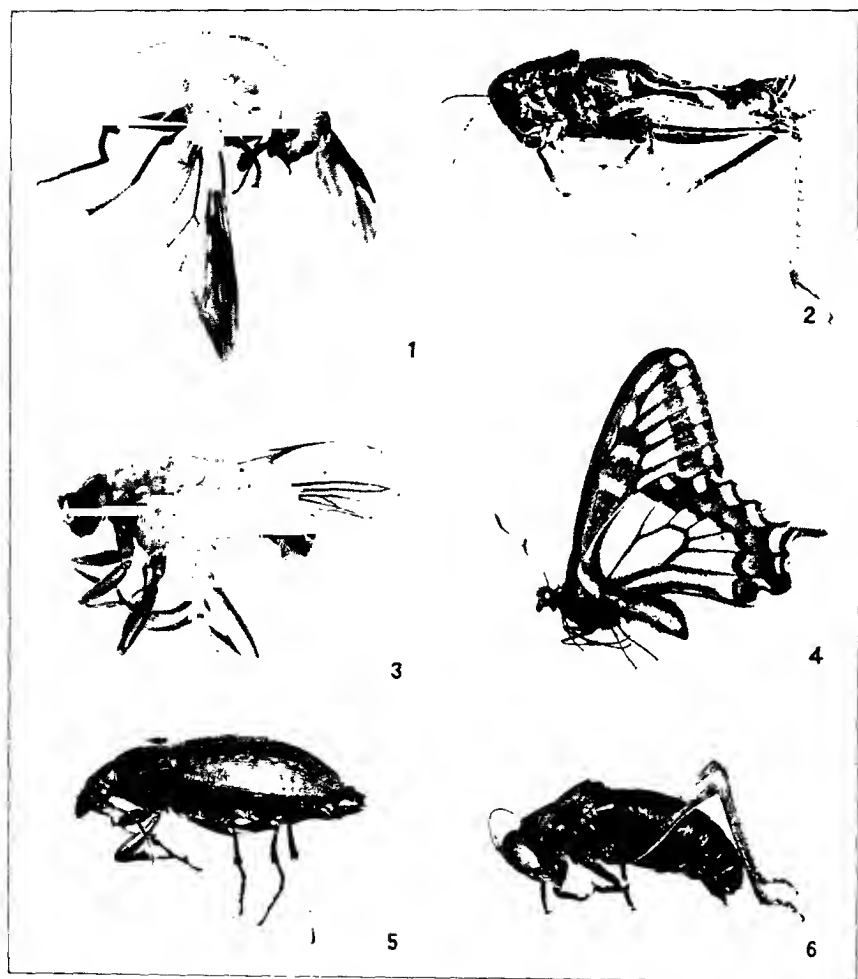


B. MAZAMA RIDGE AT THE TIMBER LINE. BURIED IN SNOW NINE MONTHS OF THE YEAR, TREES AT THE TIMBER LINE HAVE A HARD, SLOW STRUGGLE FOR LIFE



MOUNT RAINIER INSECTS. (ALL FIGURES OF PLATE 8 MAGNIFIED APPROXIMATELY TWO DIAMETERS, EXCEPT FIGURE 9, WHICH IS ALMOST NATURAL SIZE.)

1. *Acetophila dagrans*, a mountain-syrphid.
2. *Acetophila harrisi*, previously known only from British Columbia.
3. *Anthrax curtipisoni*, a robust bee fly.
4. "Echinomyia thomasi," a c., *Rhachogaster Lermodei*, a cutworm parasite. Note the torn wings.
5. *Cincindella depressula*, a mountain tiger beetle.
6. *Thecophora* - *Ectonus harrisi*, the slender bee fly of the ghost trees.
7. *Calyprobola utcheri*, a metallic bronzed syrphid.
8. *Cyrtosoma dyxilis*, a mountain robber fly.
9. *Euclyptus cyaneus*, the steel-blue hornet wasp.
10. *Sarcophaga erythraea*, a "flesh fly," parasitic on insects.
11. *Loricis rutilans*, a warlike clearwing moth.
12. *Pachyta armita*, a flower-loving longhorn beetle.



MOUNT RAINIER INSECTS.

1. *Siergomyia chalyboga*, the commonest mountain scorpionfly. $\times 2.5$.
2. *Asymptotus rainierensis*, a short-winged grasshopper found near the timber line. $\times 1.8$.
3. *Pseudogaryphala*, one of the finest of mountain scorpionflies. $\times 2$.
4. *Papilio Zoltus*, a swallowtail butterfly. Natural size.
5. *Cicadobius tectatus*, a caterpillar-hunting beetle. $\times 1.8$.
6. *Anabrus simplex* var. *maculosus*, the lubber cricket that lives near timber line. Natural size.

THE SCIENCE OF MAN: ITS NEEDS AND ITS PROSPECTS.¹

By KARL PEARSON, F. R. S.

Anthropology—the understanding of man—should be, if Pierre Charron were correct, the true science and the true study of mankind.² We might anticipate that in our days—in this era of science—anthropology in its broadest sense would occupy the same exalted position that theology occupied in the Middle Ages. We should hail it “Queen of the sciences,” the crowning study of the academic curriculum. Why is it that we are section H and not section A? If the answer be given that such is the result of historic evolution, can we still be satisfied with the position that anthropology at present takes up in our British universities and in our learned societies? Have our universities, one and all, anthropological institutes well filled with enthusiastic students, and are there brilliant professors and lecturers teaching them not only to understand man’s past, but to use that knowledge to forward his future? Have we men trained during a long life of study and research to represent our science in the arena, or do we largely trust to dilettanti—to retired civil servants, to untrained travelers or colonial medical men for our knowledge, and to the anatomist, the surgeon, or the archeologist for our teaching? Needless to say, that for the study of man we require the better part of many sciences; we must draw for contributions on medicine, on zoology, on anatomy, or archeology, on folk-lore and travel-lore, nay, on history, psychology, geology, and many other branches of knowledge. But a hotchpotch of the facts of these sciences does not create anthropology. The true anthropologist is not the man who has merely a wide knowledge of the conclusions of other sciences, he is the man who grasps their bearing on mankind and throws light on the past and present factors of human evolution from that knowledge.

¹ Presidential address to Section H of the British Association for the Advancement of Science, Cardiff, 1920. Reprinted by permission of the British Association.

² “La vraie science et le vrai estude de l’homme c’est l’Homme.” Pierre Charron, *De la Sagesse*, Préface du Premier Livre, 1601. Pope, with his “The proper study of mankind is Man,” 1733, was, as we might anticipate, only a plagiarist.

I am afraid I am a scientific heretic—an outcast from the true orthodox faith—I do not believe in science for its own sake. I believe only in science for man's sake. You will hear on every side the argument that it is not the aim of science to be utile, that you must pursue scientific studies for their own sake and not for the utility of the resulting discoveries. I think that there is a great deal of obscurity about this attitude, I will not say nonsense. I find the strongest supporters of "science for its own sake" use as the main argument for the pursuit of not immediately utile researches that these researches will be useful some day, that we can never be certain when they will turn out to be of advantage to mankind. Or, again, they will appeal to non-utile branches of science as providing a splendid intellectual training—as if the provision of highly trained minds was not itself a social function of the greatest utility! In other words, the argument from utility is in both cases indirectly applied to justify the study of science for its own sake. In the old days the study of hyperspace—space of higher dimensions than that of which we have physical cognizance—used to be cited as an example of a non-utile scientific research. In view of the facts: (i) that our whole physical outlook on the universe—and with it I will add our whole philosophical and theological outlooks—are taking new aspects under the theory of Einstein; and (ii) that study of the relative influences of nature and nurture in man can be reduced to the trigonometry of polyhedra in hyperspace—we see how idle it is to fence off any field of scientific investigation as nonutile.

Yet are we to defend the past of anthropology—and, in particular, of anthropometry—as the devotion of our science to an immediate nonutile which one day is going to be utile in a glorious and epoch-making manner, like the Clifford-Einstein suggestion of the curvature of our space? I fear we can take no such flattering unction to our souls. I fear that "the best is yet to be" can not be said of our multitudinous observations on "height-sitting" or on the censuses of eye- or hair-colors of our population. These things are dead almost from the day of their record. It is not only because the bulk of their recorders were untrained to observe and measure with scientific accuracy, it is not only because the records in 9 out of 10 cases omit the associated factors, without which the record is valueless. It is because the progress of mankind in its present stage depends on characters wholly different from those which have so largely occupied the anthropologist's attention. Seizing the superficial and easy to observe, he has let slip the more subtle and elusive qualities on which progress, on which national fitness for this or that task, essentially depends. The pulse-tracing, the reaction-time, the mental age of the men under his control, are far more important to the commanding officer—nay, I will add, to the employer of labor—than any record

of span, of head measurement, or of pigmentation categories. The psychophysical and psychophysiological characters are of far greater weight in the struggle of nations to-day than the superficial measurements of man's body. Physique, in the fullest sense, counts something still, but it is physique as measured by health, not by stature or eye-color. But character, strength of will, mental quickness count more, and if anthropometry is to be useful to the State it must turn from these rusty old weapons, these measurements of stature and records of eye-color to more certain appreciations of bodily health and mental aptitude—to what we may term "vigorimetry" and to psychometry.

Some of you may be inclined to ask: And how do you know that these superficial size-, shape-, and pigment-characters are not closely associated with measurements of soundness of body and soundness of mind? The answer to this question is twofold, and I must ask you to follow me for a moment into what appears a totally different subject. I refer to a "pure race." Some biologists apparently believe they can isolate a pure race, but in the case of man, I feel sure that purity of race is a merely relative term. For a given character one race is purer than a second, if the scientific measure of variation of that character is less than it is in the second. In loose wording, for we can not express ourselves accurately without mathematical symbols, that race is purer for which on the average the individuals are closer to type for the bulk of ascertainable characters than are the characters in a second race. But an absolutely pure race in man defies definition. The more isolated a group of men has remained, the longer it has lived under the same environment, and the more limited its habitat, the less variation from type it will exhibit, and we can legitimately speak of it as possessing greater purity. We, most of us, probably believe in a single origin of man. But as anthropologists we are inclined to speak as if at the dawn of history there were a number of pure races, each with definite physical and mental characteristics; if this were true, which I do not believe, it could only mean that up to that period there had been extreme isolation, extremely differentiated environments, and thus marked differences in the direction and rate of mental and physical evolution. But what we know historically of folk wanderings, folk mixings, and folk absorptions has undoubtedly been going on prehistorically for hundreds of thousands of years, of which we have recorded only a small historic fragment. Have we any real reason for supposing that "purity of race" existed up to the beginning of history, and that we have all got badly mixed up since?

Let us, however, grant that there were purer races at the beginning of history than we find to-day. Let us suppose a Nordic race with a certain stature, a given pigmentation, a given shape of head, and a

given mentality. And, again, we will suppose an Alpine race, differing markedly in type from the Nordic race. What happens if we cross members of the two races and proceed to a race of hybrids? A Mendelian would tell us that these characters are sorted out like cards from a pack in all sorts of novel combinations. A Nordic mentality will be found with short stature and dark eyes. A tall but brachycephalic individual will combine Alpine mentality with blue eyes. Without accepting fully the Mendelian theory we can at least accept the result of mass observations, which show that the association between superficial physical measurements and mentality is of the slenderest kind. If you keep within one class, my own measurements show me that there is only the slightest relation between intelligence and the size and shape of the head. Pigmentation in this country seems to have little relation to the incidence of disease. Size and shape of head in man have been taken as a rough measure of size and shape of brain. They can not tell you more—perhaps not as much as brain weight—and if brain weight were closely associated with intelligence, then man should be at his intellectual prime in his teens.

Again, too often is this idea of close association of mentality and physique carried into the analysis of individuals within a human group, *i. e.* of men belonging to one or another of the many races which have gone to build up our population. We talk as if it was our population which was mixed, and not our germplasm. We are accustomed to speak of a typical Englishman. For example, Charles Darwin; we think of his mind as a typical English mind, working in a typical English manner, yet when we come to study his pedigree we seek in vain for "purity of race." He is descended in four different lines from Irish kinglets; he is descended in as many lines from Scottish and Pictish Kings. He had Manx blood. He claims descent in at least three lines from Alfred the Great, and so links up with Anglo-Saxon blood, but he links up also in several lines with Charlemagne and the Carolingians. He sprang also from the Saxon Emperors of Germany, as well as from Barbarossa and the Hohenstaufens. He had Norwegian blood and much Norman blood. He had descent from the Dukes of Bavaria, of Saxony, of Flanders, the Princes of Savoy, and the Kings of Italy. He had the blood in his veins of Franks, Alamans, Merovingians, Burgundians, and Longobards. He sprang in direct descent from the Hun rulers of Hungary and the Greek Emperors of Constantinople. If I recollect rightly, Ivan the Terrible provided a Russian link. There is probably not one of the races of Europe concerned in the folk wanderings which has not a share in the ancestry of Charles Darwin. If it has been possible in the case of one Englishman of this kind to show in a considerable number of lines how impure is his race, can we venture to assert that if the like knowledge were possible of attainment, we

could expect greater purity of blood in any of his countrymen? What we are able to show may occur by tracing an individual in historic times, have we any valid reason for supposing did not occur in prehistoric times, wherever physical barriers did not isolate a limited section of mankind? If there ever was an association of definite mentality with physical characters, it would break down as soon as race mingled freely with race, as it has done in historic Europe. Isolation or a strong feeling against free interbreeding—as in a color differentiation—could alone maintain a close association between physical and mental characters. Europe has never recovered from the general hybridization of the folk wanderings, and it is only the cessation of wars of conquest and occupation, the spread of the conception of nationality and the reviving consciousness of race, which is providing the barriers which may eventually lead through isolation to a new linking up of physical and mental characters.

In a population which consists of nonintermarrying castes, as in India, physique and external appearance may be a measure of the type of mentality. In the highly and recently hybridized nations of Europe there are really but few fragments of "pure races" left, and it is hopeless to believe that anthropometric measurements of the body or records of pigmentation are going to help us to a science of the psychophysical characters of man which will be useful to the State. The modern State needs in its citizens vigor of mind and vigor of body, but these are not characters with which the anthropometry of the past has largely busied itself. In a certain sense the school medical officer and the medical officer of health are doing more State service of an anthropological character than the anthropologists themselves.

These doubts have come very forcibly to my notice during the last few years. What were the anthropologists as anthropologists doing during the war? Many of them were busy enough and doing valuable work because they were anatomists, or because they were surgeons, or perhaps even because they were mathematicians. But as anthropologists, what was their position? The whole period of the war produced the most difficult problems in folk psychology. There were occasions innumerable when thousands of lives and most heavy expenditure of money might have been saved by a greater knowledge of what creates and what damps folk movements in the various races of the world. India, Egypt, Ireland, even our present relations with Italy and America, show only too painfully how difficult we find it to appreciate the psychology of other nations. We shall not surmount these difficulties until anthropologists take a wider view of the material they have to record, and of the task they have before them if they wish to be utile to the State. It is not the physical measurement of native races which is a fundamental feature of anthropome-

try to-day; it is the psychometry and what I have termed the vigormetry of white- as well as of dark-skinned men that must become the main subjects of our study.

Some of you may consider that I am overlooking what has been contributed both in this country and elsewhere to the science of folk psychology. I know at least that Wilhelm Wundt's³ great work runs to ten volumes. But I also know that in its 5,452 pages there is not a single table of numerical measurements, not a single statement of the *quantitative* association between mental racial characters, nor, indeed, any attempt to show numerically the intensity of association between folk mentality and folk customs and institutions. It is folk psychology in the same stage of evolution as present-day sociology is in, or as individual psychology was in before the advent of experimental psychology and the correlational calculus. It is purely descriptive and verbal. I am not denying that many sciences must for a long period still remain in this condition, but at the same time I confess myself a firm disciple of Friar Roger Bacon⁴ and of Leonardo da Vinci,⁵ and believe that we can really know very little about a phenomenon until we can actually measure it and express its relations to other phenomena in quantitative form. Now you will doubtless suggest that sections of folk psychology like language, religion, law, art—much that forms the substance of cultural anthropology—are incapable of quantitative treatment. I am not convinced that this standpoint is correct. Take only the first of these sections—*language*. I am by no means certain that there is not a rich harvest to be reaped by the first man who can give unbroken time and study to the statistical analysis of language. Whether he start with roots or with words to investigate the degree of resemblance in languages of the same family, he is likely, before he has done, to learn a great deal about the relative closeness and order of evolution of cognate tongues, whether those tongues be Aryan or Sudanese. And the methods applicable in the case of language will apply in the same manner to cultural habits and ideas. Strange as the notion may seem at first, there is a wide field in cultural anthropology for the use of those same methods which have revolutionised psychometric technique, to say nothing of their influence on osteometry.

The problems of cultural anthropology are subtle, but so indeed are the problems of anthropometry, and no instrument can be too

³ Its last volume also bears evidence of the non-judicial mind of the writer, who expresses strong opinions about recent events in the language of the party historian rather than the man of science.

⁴ He who knows not mathematics can not know any other science, and what is more can not discover his own ignorance or find its proper remedies.

⁵ *Nissuna humana investigatione si po dimandare vera scientia s'essa non passa per le mathematiche dimostrazione.*

fine if our analysis is to be final. The day is past when the arithmetic of the kindergarten sufficed for the physical anthropologist; the day is coming when mere verbal discussion will prove inadequate for the cultural anthropologist.

I do not say this merely in the controversial spirit. I say it because I want to find a remedy for the present state of affairs. I want to see the full recognition of anthropology as a leading science by the State. I want to see the recognition of anthropology by our manufacturers and commercial men, for it should be at least as important to them as chemistry or physics—the foundation of anthropological institutes with their museums and professors in Hamburg and Frankfurt have not yet found their parallels in commercial centers here. I want to see a fuller recognition of anthropology in our great scientific societies, both in their choice of members and in the memoirs published. If their doors are being opened to psychology under its new technique, may not anthropology also seek for fuller recognition?

It appears to me that if we are to place anthropology in its true position as the Queen of the sciences, we must work shoulder to shoulder and work without intermittence in the following directions: Anthropologists must not cease—

(1) To insist that our recorded material shall be such that it is at present or is likely in the near future to be utile to the State, using the word "State" in its amplest sense.

(2) To insist that there shall be institutes of anthropology, each with a full staff of qualified professors, whose whole energy and time shall be devoted to the teaching of and research in anthropology, ethnology, and prehistory. At least three of our chief universities should be provided with such institutes.

(3) To insist that our technique shall not consist in the mere statement of opinion on the facts observed, but shall follow, if possible, with greater insight, the methods which are coming into use in epidemiology and psychology.

I should like to enlarge a little further on these three insistentencies, the fundamental "planks" of the campaign I have in view.

1. INSISTENCE ON THE NATURE OF THE MATERIAL TO BE DEALT WITH.

I have already tried to indicate that the problems before us to-day, the grave problems that are pressing on us with regard to the future, can not be solved by the old material and by the old methods. We have to make anthropology a wise counsellor of the State, and this means a counsellor in political matters, in commercial matters, and in social matters.

The Governments of Europe have had military advisers, financial advisers, transport and food experts in their service, but they have not had ethnological advisers; there have been no highly trained anthropologists at their command. You have only to study the peace of Versailles to see that it is ethnologically unsound and can not be permanent. It is no good asking why our well-meaning rulers did not consult our well-meaning anthropologists. I for one confess that we have not in the past dealt with actuality, or if we did deal with actuality, that we have not treated it in a manner likely to impress either the executive or the public at large. There lacked far too often the scientific attitude and the fundamental specialist training. I will not go so far as to say that, if the science of man had been developed to the extent of physical science in all European countries, and had then had its due authority recognized, there would have been no war, but I will venture to say that the war would have been of a different character, and we should not have felt that the fate of European society and of European culture hung in the balance, as at this moment they certainly do.

No one can allow individual inspiration to-day, and you may justly cry a Daniel has no right to issue judgment from the high seat of the feast. Daniel's business is that of the outsider, the stranger, the unwelcome person interpreting, probably his own, scrawling on the wall.

Well, if it be hard to learn from friends, let us at least study impassionately from our late foes. Some of my audience may have read the recent manifesto of the German anthropologists, their clarion cry for a new and stronger position of the science of man in academic studies. But the manifesto may have escaped some, and so closely does it fit the state of affairs here that I venture to quote certain portions of it. After reciting the sparsity of chairs for the study of physical and cultural anthropology in the German universities and how little academic weight has been given to such studies, it continues:

Where these sciences have otherwise found recognition in the universities, they are not represented by specialists, so that anthropology is provided for by the anatomists, ethnology by the geographers, and prehistory by Germanists, archeologists and geologists, and this although, in the present extent of these three sciences, the real command of each one of them demands the complete working powers of an individual. This want of teaching posts had made itself felt long before the war, so that the number of specialists and of those interested in our science has receded.*

And again:

During the war we have often experienced how in political pamphlets ethnology and ethnography—even as in the peace treaty of Brest-Litovsk—were

* Correspondenz Blatt, u. s. w., Jahrg. 1., S. 37.

used too often as catchwords without their users being clear about the ideas those words convey. The sad results of our foreign policy, the collapse of all our calculations as to national frames of mind, were based in no small degree on ethnographic ignorance; one has only to take for example the case of the Turks. Ethnology should not embrace only the spears and clubs of the savages, but also the psychology and demography of the white races, the European peoples. At this very moment, when the right of self-determination has become a foremost question of the day, the scientific determination of the boundaries of a people and its lands has become a task of the first importance. But our Government of the past knew nothing of the activity of the ethnologists, and the universities were not in the condition to come to their aid, for ethnological chairs and institutes were wanting. The foundation of such must be the task of the immediate future.⁷

And once more:

The problems of the military fitness of our people, of the physical constitution of the various social classes, of the influence of the social and material environment upon them, the problems of the biological grounds for the fall in the birth rate and its results, of the racial composition of our people, of the eventual racial differences and the accompanying diverse mental capacities of the individual strata, and finally the racial changes which may take place in a folk under the influences of civilization, and the bearing of all these matters on the fate of a nation, these are problems which can alone be investigated and brought nearer to solution by anthropology. Even now after the war-population problems stand in the forefront of interest, the question of folk-increase and of the falling birth rate is the vital question of the future.⁸

I must ask your pardon for quoting so much, but it seems so strongly to point the moral of my tale. If you will study what Germany is feeling and thinking to-day, do not hope to find it in the newspaper reports; seek it elsewhere in personal communication or in German writings. Then, I think, you will agree with me that rightly or wrongly there is a conviction spreading in Germany that the war arose and that the war was lost because a nation of professed thinkers had studied all sciences but had omitted to study aptly the science of man. And in a certain sense that is an absolutely correct conviction, for if the science of man stood where we may hope it will stand in the dim and distant future, man would from the past and the surrounding present have some grasp of future evolution, and so have a greater chance of guiding its controllable factors.

We are far indeed from that to-day; but it befits us none the less to study what this new anthropological movement in Germany connotes. It means that the material of anthropology is going to change, or rather that its observations will be extended into a study of the mental as well as the physical characters, and these of the white races as well as of the dark. It means that anthropologists will not only study individual psychology, but folk psychology. It means—and this is directly said—that Germany, having lost her colonies, will

⁷ *Ibid.* S. 41.

⁸ *Ibid.* S. 38.

still maintain her trade by aid of consuls, missionaries, traders, travelers, and others trained academically to understand both savage and civilized peoples. This is a perfectly fair field, and if the game be played squarely can solely lead to increased human sympathy, and we shall only have ourselves to blame if other nations are before us in their anthropological knowledge and its practical applications. The first condition for State support is that we show our science to be utile by turning to the problems of racial efficiency and of race psychology, and to all those tasks that Galton described as the first duty of a nation—"in short, to make every individual efficient both through nature and by nurture."

Does this mean that we are to turn our backs on the past, to desert all our prehistoric studies and to make anthropology the servant of sanitation and commerce? Not in the least; if you think this is my doctrine I have indeed failed to make myself even roughly clear to-day. Such teaching is wholly opposed to my view of the function of science. I feel quite convinced that you can not understand man of to-day, savage or civilized, his body or his mind, unless you know his past evolution, unless you have studied fully all the scanty evidence we have of the stages of his ascent. I should like to illustrate this by an incident which came recently to my notice, because it may indicate to some of those present the difficulties with which the anthropologist has to contend to avoid misunderstanding.

Looking into the ancestry of man and tracing him backward to a being who was not man and was not ape, we ask had this prot-simio-human, in the light of our present knowledge, more resemblance to the gibbon or to the chimpanzee as we know them to-day? Some naturalists link man up to the apes by a gibbonlike form, others by a troglodyte type of ancestor. Some would make a push to do without either. But granted the alternative, which is the more probable? This is the problem of the hylobatic or the troglodyte origin of man. I had given a lecture on the subject, confining my arguments solely to characters of the thigh-bone. Now there chanced to be a statesman present, a man who has had large responsibilities in the government of many races. I have been honored by seeing his comments on my lecture. "I am not," he says, "particularly interested in the descent of man. I do not believe much in heredity, and this scientific pursuit of the dead bones of the past does not seem to me a very useful way of spending life. I am accustomed to this mode of study; learned volumes have been written in Sanscrit to explain the conjunction of the two vowels 'a' and 'u.' It is very learned, very ingenious, but not very helpful. * * * I am not concerned with my genealogy so much as with my future. Our intellects can be more advantageously employed than in finding our diversity from the ape * * *. There may be no spirit, no soul; there is no proof of their

existence. If that is so, let us do away with shams and live like animals. If, on the other hand, there is a soul to be looked after, let us all strain our nerves to the task; there is no use in digging into the sands of time for the skeletons of the past; build your man for the future."

What is the reply of anthropology to this indictment of the statesman? You can not brush it lightly aside. It is the statement of a good man and a strong man who is willing to spend his life in the service of his fellows. He sees us handling fossils and potsherds and can not perceive the social utility of our studies. He does not believe any enthusiasm for human progress can lie beneath the spade and callipers of the scientific investigator. He has never grasped that the man of to-day is precisely what heredity and his genealogy, his past history and his prehistory, have made him. He does not recognise that it is impossible to build your man for the future until you have studied the origin of his physical and mental constitution. Whence did he draw his good and evil characteristics—are they the product of his nature or his nurture? Man has not a plastic mind and body which the enthusiastic reformer can at will mould to the model of his golden age ideals. He has taken thousands of years to grow into what he is, and only by like processes of evolution—intensified and speeded up, if we work consciously and with full knowledge of the past—can we build his future.

It *does* matter in regard to the gravest problems before mankind to-day whether our ancestry was hylobatic or troglodyte. For five years the whole world has been a stage for brutality and violence. We have seen a large part of the youth of Europe who were best fitted mentally and physically to be parents of future generations perish: the dysgenic effect of this slaughter will show itself each 20 to 25 years for centuries to come in the census returns of half the countries of the world. Science undertook work which national feeling bade it do, but on which it will ever look back with a shuddering feeling of distaste, an uneasy consciousness of having soiled its hands. And as aftermath we see in almost every land an orgy of violent crime, a sense of lost security, and at times we dread that our very civilization may perish owing to the weakening of the social ties, the deadening of the responsibilities of class to class. This outbreak of violence which has so appalled the thinking world, is it the sporadic appearance of an innate passion for the raw and brutal in mankind, or is it the outcome of economic causes forcing the nations of the world to the combat for limited food and material supplies? I wish we could attribute it to the latter source, for then we could eradicate the spirit of violence by changing environmental conditions. But if the spirit of violence be innate in man, if there

be times when he not only sees red but rejoices in it—and that was the strong impression I formed when I crossed Germany on August 1, 1914—then outbreaks of violence will not cease till troglodyte mentality is bred out of man. That is why the question of troglodyte or hylobatic ancestry is not a pursuit of dead bones. It is a vital problem on which turns much of folk psychology. It is a problem utile to the State, in that it throws light on whether nature or nurture is the more likely to build up man's future—and save him from the recurrence of such another quinquennium.

The critic to whom I have referred was not idle in his criticism. He had not been taught that evolutionary doctrine has its bearings on practical life. The biologist and the anthropologist are at fault; they have too often omitted to show that their problems have a very close relation to those of the statesman and the social reformer, and that the problems of the latter can not be solved without a true insight into man's past, without a knowledge of the laws of heredity, and without a due appreciation of the causes which underlie great folk-movements.

2. INSISTENCE ON INSTITUTES OF ANTHROPOLOGY.

The anthropological problems of the present day are so numerous and so pressing that we can afford to select those of the greatest utility. Indeed, the three university institutes of anthropology I have suggested would have to specialize and then work hard to keep abreast of the problems which will crowd upon them. One might take the European races, another Asia and the Pacific, and a third Africa. America in anthropology can well look after itself. In each case we need something on the scale of the Paris École d'Anthropologie, with its 17 professors and teachers, with its museums and journals. But we want something else—a new conception of the range of problems to be dealt with and a new technique. From such schools would pass out men with academic training fit to become officials, diplomatic agents, teachers, missionaries, and traders in Europe, in Asia, or in Africa, men with intelligent appreciation of and sympathy with the races among whom they proposed to work.

But this extra-State work, important as it is, is hardly comparable in magnitude with the intra-State work which lies ready to hand for the anthropological laboratory that has the will, the staff, and the equipment to take it up efficiently. In the present condition of affairs it is only too likely that much of this work, being psychometric, will fall into the hands of the psychologist, whereas it is essentially the fitting work of the anthropologist, who should come to the task, if fitly trained, with a knowledge of comparative material and of the past history, mental and physical, of mankind, on which his present faculties so largely depend. The danger has arisen because the

anthropometer has forgotten that it is as much his duty to measure the human mind as it is his duty to measure the human body, and that it is as much his duty to measure the functional activities of the human body—its dynamical characters—as its statical characters. By dynamical characters I understand such qualities as resistance to fatigue, facility in physical and mental tasks, immunity to disease, excitability under stimuli, and many kindred properties. If you tell me that we are here trenching on the field of psychology and medicine. I reply: Certainly; you do not suppose that any form of investigation which deals with man—body or mind—is to be omitted from the science of man? If you do you have failed to grasp why anthropology is the queen of the sciences. The university anthropological institute of the future will have attached to it a psychologist, a medical officer, and a biologist. They are essential portions of its requisite staff, but this is a very different matter from lopping off large and important branches of its fitting studies, to lie neglected on the ground, or to be dragged away, as dead wood, to be hewn and shapen for other purposes by scientific colleagues in other institutes. Remember that I am emphasizing that side of anthropology which studies man in the service of the State—anthropology as a utile science—and that this is the only ground on which anthropology can appeal for support and sympathy from State, from municipality, and from private donors. You will notice that I lay stress on the association of the anthropological institute with the university, and the reasons for this are manifold. In the first place, every science is stimulated by contact with the workers in allied sciences; in the second place, the institute must be a teaching as well as a researching body, and it can only do this effectively in association with an academic center—a center from which to draw its students and recruit its staff. In the third place, a great university provides a wide field for anthropometric studies in its students and its staff. And the advantages are mutual. It is not of much service to hand a student a card containing his stature, his weight, his eye-color, and his head-length. Most of these he can find out for himself. But it is of importance to him to know something of how his eye, heart, and respiration function; it is of importance to him to know the general character of his mental qualities, and how they are associated with the rapidity and steadiness of muscular responses. Knowledge on these points may lead him to a fit choice of a career, or at any rate save him from a thoroughly bad choice.

In the course of my life I have often received inquiries from schoolmasters of the following kind: We are setting up a school anthropometric laboratory, and we propose to measure stature, weight, height-sitting, &c. Can you suggest anything else we should measure?

My invariable reply is: Don't start measuring anything at all until you have settled the problems you wish to answer, and then just measure the characters in an adequate number of your boys, which will enable you to solve those problems. Use your school as a laboratory, not as a weighhouse.

And I might add, if I were not in dread of giving offense: And most certainly do not measure anything at all if you have *no* problem to solve, for unless you have you can not have the true spirit of the anthropologist, and you will merely increase that material up and down in the schools of the country which nobody is turning to any real use.

Which of us, who is a parent, has not felt the grave responsibility of advising a child on the choice of a profession? We have before us, perhaps, a few meager examination results, an indefinite knowledge of the self-chosen occupations of the child, and perhaps some regard to the past experience of the family or clan. Possibly we say John is good with his hands and does not care for lessons; therefore he should be an engineer. That may be a correct judgment if we understand by engineer, the engine driver or mechanic. It is not true if we think of the builders of Forth Bridges and Assuan Dams. Such men work with the head and not the hand. One of the functions of the anthropological laboratory of a great university, one of the functions of a school anthropometric laboratory, should be to measure those physical and mental characters and their interrelations upon which a man's success in a given career so much depends. Its function should be to guide youth in the choice of a calling, and in the case of a school to enable the headmaster to know something of the real nature of individual boys, so that that much-tried man does not feel compelled to hide his ignorance by cabalistic utterances when parents question him on what their son is fitted for.

Wide, however, as is the anthropometric material in our universities and public schools, it touches only a section of the population. The modern anthropologist has to go further; he has to enter the doors of the primary schools; he has to study the general population in all its castes, in its craftsmen, and its sedentary workers. Anthropology has to be useful to commerce and to the State, not only in association with foreign races, but still more in the selection of the right men and women for the staff of factory, mine, office, and transport. The selection of workmen to-day by what is too often a rough trial and discharge method is one of the wasteful factors of production. Few employers even ask what trades parents and grandparents have followed, nor consider the relation of a man's physique and mentality to his proposed employment. I admit that progress in this direction will be slow, but if the work undertaken in this sense by

the anthropologist be well devised, accurate, and comprehensive, the anthropometric laboratory will gradually obtain an assured position in commercial appreciation. As a beginning, the anthropologist by an attractive museum, by popular lectures and demonstrations, should endeavour to create, as Sir Francis Galton did at South Kensington, an anthropometric laboratory, frequented by the general population as well as by the academic class. Thus he will obtain a wider range of material. But the anthropologist, if he is to advance his science and emphasize its services to the State, must pass beyond the university, the school, and the factory. He must study what makes for wastage in our present loosely organized society; he must investigate the material provided by reformatory, prison, asylums for the insane and mentally defective: he must carry his researches into the inebriate home, the sanatorium, and the hospital, side by side with his medical collaborator. Here is endless work for the immediate future, and the work in which we are already leagues behind our American colleagues. For them the psychometric and anthropometric laboratory attached to asylum, prison, and reformatory is no startling innovation, to be spoken of with bated breath. It is a recognized institution of the United States to-day, and from such laboratories the "fieldworkers" pass out, finding out and reporting on the share parentage and environment have had in the production of the abnormal and the diseased, of the anti-social of all kinds. Some of this work is excellent, some indifferent, some perhaps worthless, but this will always be the case in the expansion of new branches of applied science. The training of the workers must be largely of an experimental character, the technique has to be devised as the work develops. Instructors and directors have to be appointed, who have not been trained *ad hoc*. But this is remedying itself, and if, indeed, when we start we also do not at first limp somewhat lamely along these very paths, it will only be because we have the advantage of American experience.

There is little wonder that in America anthropology is no longer the stepchild of the State. It has demanded its heritage and shown that it can use it for the public good.

If I have returned to my first insistence that the problems handled by the anthropologist shall be those useful to the State, it is because I have not seen that point insisted upon in this country, and it is because my first insistence, like my third, involves the second for its effectiveness—the establishment in our chief universities of anthropological institutes. As Gustav Schwalbe said of anthropology in 1907—and he was a man who thought before he spoke, and whose death during the war is a loss to anthropologists the whole world over:

A lasting improvement can only arise if the State recognizes that anthropology is a science preeminently of value to the State, a science which not only deserves but can demand that chairs shall be officially established for it in every university. * * * Only this spread of officially authorized anthropology in all German universities can enable it to fulfil its task—that of training men who, well armed with the weapon of anthropological knowledge, will be able to place their skill at the service of the State, which will ever have need of them in increasing numbers.*

Our universities are not, as in Germany, Government controlled institutions, although such control is yearly increasing. Here we have first to show that we are supporting the State before the State somewhat grudgingly will give its support to us. Hence the immediate aim of the anthropologist should be—not to suggest that the State should *a priori* assist work not yet undertaken, but to do what he can with the limited resources in his power, and when he has shown that what he has achieved is, notwithstanding his limitations, of value to the State, then he is in a position to claim effective support for his science.

I have left to myself little time to place fairly before you my third insistence.

3. INSISTENCE ON THE ADOPTION OF A NEW TECHNIQUE.

What is it that a young man seeks when he enters the university, if we put aside for a moment any social advantages, such as the formation of lifelong friendships associated therewith? He seeks, or ought to seek, training for the mind. He seeks, or ought to seek, an open doorway to a calling which will be of use to himself, and wherein he will take his part, a useful part, in the social organization of which he finds himself a member. Much as we may all desire it, in the pressure of modern life, it is very difficult for the young man of moderate means to look upon the university training as something apart from his professional training. Men more and more select their academic studies with a view to their professional value. We can no longer combine the senior wranglership with the pursuit of a judgeship; we can not pass out in the classical tripos and aim at settling down in life as a Harley Street consultant; we can not take a D. Sc. in chemistry as a preliminary to a journalistic career. It is the faculties which provide professional training that are crowded, and men study nowadays physics or chemistry because they wish to be physicists or chemists, or seek by their knowledge of these sciences to reach commercial posts. Even the faculty of arts itself runs the danger of becoming a professional school for elementary school teachers. I do not approve this state of affairs; I would merely note its existence. But granted it, what does anthropology

* Correspondenz Blatt, Jahrg. xxxviii., S. 68.

offer to the young man who for a moment considers it as a possible academic study? There are no professional posts at present open to him, and few academic posts.¹⁰ There is little to attract the young man to anthropology as a career. Is its position as a training of mind any stronger? The student knows if he studies physics or chemistry or engineering that he will obtain a knowledge of the principles of observation, of measurement, and of the interpretation of data which will serve him in good stead whenever he has to deal with phenomena of any kind. But, alas! in anthropology, while he finds many things of surpassing interest, he discovers no generally accepted methods of attacking new problems, *quot homines, tot sententie*. The type of man we want in anthropology is precisely the man who now turns to mathematics, to physics, and to astronomy—the man with an exact mind who will not take statements on authority and who believes in testing all things. To such a man anthropometry—in all its branches, craniometry, psychometry, and the wide field in which body and mind are tested together under dynamic conditions—forms a splendid training, *provided* his data and observations are treated as seriously as those of the physicist or astronomer by adequate mathematical analysis. Such a type of man is at once repelled from our science if he finds in its textbooks and journals nothing but what has been fitly termed “kindergarten arithmetic.” Why, the other day I saw in a paper by a distinguished anthropologist an attempt to analyse how many individual bones he ought to measure. He adopted the simple process of comparing the results he obtained when he took 10, 20, 30 individuals. He was not really wiser at the end of his analysis than at the beginning, though he thought he was. And this, notwithstanding that the whole matter has been thrashed out scientifically by John Bernoulli two centuries ago, and that its solution is a commonplace of physicists and astronomers!

How can we expect the scientific world to take us seriously and to treat anthropology as the equal of other sciences while this state of affairs is possible? What discipline in logical exactness are we offering to academic youth which will compare with that of the older sciences? What claim have we to advise the State until we have introduced a sounder technique and ceased to believe that anthropometry is a science that any man can follow, with or without training? As I have hinted, the problems of anthropology seem to me as subtle as those of physical astronomy, and we are not going to solve them with rusty weapons, nor solve them at all unless we can persuade the “brainy boys” of our universities that they are worthy of keen

¹⁰ In London, for example, there is a reader in physical anthropology who is a teacher in anatomy, and a professorship in ethnology, which for some mysterious reason is included in the faculty of economics and is, I believe, not a full-time appointment.

minds. Hence it seems to me that the most fertile training for academic purposes in anthropology is that which starts from anthropometry in its broadest sense, which begins to differentiate caste and class and race, bodily and mental health and disease, by measurement and by the analysis of measurement. Once this sound grounding has been reached the trained mind may advance to ethnology and sociology, to prehistory and the evolution of man. And I shall be surprised if equal accuracy of statement and equal logic of deduction be not then demanded in these fields, and I am more than half convinced, nay, I am certain, that the technique the student will apply in anthropometry can be equally well applied in the wider fields into which he will advance in his later studies. Give anthropology a technique as accurate as that of physics, and it will forge ahead as physics has done, and then anthropologists will take their due place in the world of science and in the service of the State.

Francis Galton has a claim upon the attention of anthropologists which I have not. He has been President of your Institute, and he spoke just 35 years ago from the chair I now occupy, pressing on you for the first time the claims of new anthropological methods. In Galton's words: "Until the phenomena of any branch of knowledge have been submitted to measurement and number it can not assume the status and dignity of a science." Have we not rather forgotten those warning words, and do they not to some extent explain why our universities and learned societies, why the State and statesmen, have turned the cold shoulder on anthropology?

This condition of affairs must not continue; it is good neither for anthropology, nor for the universities, nor for the State if this fundamental science, the science of man, remains in neglect. It will not continue if anthropologists pull together and insist that their problems shall not fail in utility, that their scientific technique shall be up to date, and that anthropological training shall be a reality in our universities—that these shall be fully equipped with museums, with material, with teachers and students.

It is almost as difficult to reform a science as it is to reform a religion; in both cases the would-be reformer will offend the sacrosanct upholders of tradition, who find it hard to discard the faith in which they have been reared. But it seems to me that the difficulties of our time plead loudly for a broadening of the purpose and a sharpening of the weapons of anthropology. If we elect to stand where we have done, then a new science will respond to the needs of state and society; it will spring from medicine and psychology, it will be the poorer in that it knows little of man's development, little of his history or prehistory. But it will devote itself to the urgent problems of the day. The future lies with the nation that most truly

plans for the future, that studies most accurately the factors which will improve the racial qualities of future generations either physically or mentally. Is anthropology to lie outside this essential function of the science of man? If I understand the recent manifesto of the German anthropologists, they are determined it shall not be so. The war is at an end, but the critical time will be with us again, I sadly fear, in 20 to 30 years. How will the States of Europe stand then? It depends to no little extent on how each of them may have cultivated the science of man and applied its teaching to the improvement of national physique and mentality. Let us take care that our Nation is not the last in this legitimate rivalry. The organization of existing human society with a view to its future welfare is the crowning task of the science of man; it needs the keenest-minded investigators, the most stringent technique, and the utmost sympathy from all classes of society itself. Have we, as anthropologists, the courage to face this greatest of all tasks in the light of our knowledge of the past and with our understanding of the folk of to-day? Or shall we assert that anthropology is after all only a small part of the science of man, and retreat to our study of bones and potsherds on the ground that science is to be studied for its own sake and not for the sake of mankind? I do not know what answer you will give to that question, yet I am convinced what the judgment of the future on your answer is certain to be. It will be similar to Wang Yang Ming's reproof of the complacency of the Chinese cultured classes of his day: "Thought and learning are of little value, if they be not translated into action."

PIGMENTATION IN THE OLD AMERICANS, WITH NOTES ON GRAYING AND LOSS OF HAIR.¹

By ALEŠ HRDLÍČKA.

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INTRODUCTION.

By anthropology of the Old Americans is meant the status, physically, physiologically, and demographically, of the oldest parts of the white population of the United States, as contrasted with the American population at large and with other units of the white race.

Since discovery this country has been an ever-increasing eddy that drew in, and still draws the offshoots and surplus of a wide range of white populations in the older parts of the world, and a large majority of these newcomers have remained, made this their permanent home, and intermingling with others have been gradually building up the great new nation.

The changed environment, the many new stimuli, the freer and more virile as well as more strenuous life, the better and more abundant nourishment, the more wholesome conditions in general, and besides all the steadily growing admixture of blood, have now been acting on the older parts of this nation for from one to over three centuries. What are the results? Here is a great natural laboratory, the subject of whose multitudinous experiments has been man himself: How has he responded, and what are the indications for the future?

¹ Reprinted by permission from the American Journal of Physical Anthropology, vol. v, No. 2, May, 1922.

Satisfactory answers to this can only be reached through intensive scientific investigation.

We observe on all sides in the American, individually and collectively, a mental freshness and vigor not equaled it seems in any other country; but these matters are difficult of proper gauging. They elude measurement or strict appraisal. But there are the physique and the physiological functions of the American stock, all of which yield more or less readily to exact determinations, the results of which would be of the utmost value. The need of such determinations has long been felt, and it was only the chronic lack of means for scientific purposes that has thus far prevented the carrying out all the the desirable research in this direction. Notwithstanding this difficulty a considerable amount of work has already been accomplished, particularly on the American child, on the students of our colleges, on the drafted men and soldiers during the Civil War as well as the more recent war,² and on some of the immigrants.

Nevertheless these studies, though highly useful, are still more or less incomplete and insufficient, and the records on the recruits and soldiers both from the Civil War and from recent wars suffer from the additional defect of not having been secured by well-trained observers and with the appropriate instruments. In none of these researches, furthermore, was there a sufficient selection of the subjects as to American ancestry. They deal with the child, student, or recruit living in America, whether really American or not. Their results are not capable of giving satisfactory answers to the questions concerning the changes already effected or being effected in that part of the population which has longest been subject to the American environment; and they give us little or no information on the general adult population.

In order to supply, as far as possible, the need in these directions the writer undertook in 1912 a systematic anthropological study of the oldest part of the "Old Americans." By "Old Americans" he designated all those whose families had no mixture with more recent elements on either side for at least three generations. The study lasted until the present year. It was carried on in the anthropological laboratory of the U. S. National Museum, but eventually also in the field, and the utmost care was exercised throughout to assure the reliability of the data secured.

The examinations comprised the most important of measurements on the body with a series of physiological tests and visual observa-

² See writer's "Physical Anthropology," 8°, Wistar Institute, Phila., 1919; *The Amer. J. Phys. Anthropol.*, 1918-21; the publications of the Children's Bureau, the Surgeon General's Office, and the U. S. Bureau of Education.

The demography of the United States is being taken care of by the U. S. Bureau of the Census and by the principal life insurance companies.

tions. They were restricted to healthy adults of both sexes of between 24 and 60 years of age and without any selection as to class or territorial derivation. The subjects were all volunteers and included members of some of the foremost American families.

The study proved throughout one of the most absorbing interest; but an unexpected difficulty developed in finding sufficient numbers of persons of the right qualifications. Native Americans whose families have two generations on each side born in this country may already be counted by the million, but those of three generations or more are far scarcer, except in certain limited inbred regions or communities. It was on this account that short trips had eventually to be taken into Massachusetts, Connecticut, Virginia, and finally the mountain region of Tennessee, where additional series of highly interesting subjects were examined.³

The final number of subjects on whom observations were made counts nearly 2,000. The large majority of them were from the Eastern States, the States that furnished the old stock to the rest of the country. In the East all the States are represented in the series from Maine to the Gulf, and a good comparison will be possible between the Yankees and the Southerners.

The first preliminary report upon these studies was made before the Nineteenth International Congress of Americanists in 1915 at Washington;⁴ the second before the recent International Eugenics Congress in New York; and a third in April, 1922, before the National Academy of Sciences in Washington. The data on pigmentation and conditions relating to the hair are embodied in this article.

DEFINITIONS.

By pigmentation we mean the amount and nature of coloring matter in the skin, eyes and hair: though the condition is also manifest in the mucous membranes, in the sclerotic, and even in other parts and tissues of the body.

The pigmentation of an individual is not the same throughout his life, and will not appear the same under all conditions. It is much influenced by age, prolonged exposure or confinement (especially the skin and hair) and state of health. In addition the appearance of the skin, eyes, and even hair will be modified by the blood (flush, paleness or blueness of skin, brightness or dullness of eye, dull dryness of hair), the state of feeling, the presence or absence of the natural sebaceous or oily coating (in the skin and hair), and the

³ In Virginia, very efficient help with the work was given by Professor Robert Bennett Bean, of the University of Virginia. After mastering the methods employed by the writer, and with the same instruments, he measured a good series of the U. S. Corps of Engineers located at that time near the University.

⁴ Published in the *Proceedings of the Congress*, Wash. 1917, pp. 582-601.

presence of minute air bubbles between the cells of the hair occasionally after great nervous strain, or normally in advancing years (grayness).

The coloring substance, or substances, the exact nature and differences of which are still a matter of some uncertainty, occurs in the shape of minute granules which, in the skin, are lodged in the deeper layers of the epidermis; in the eye, infiltrate various cells of the iris; and in the hair, are disseminated through most of the cells of the hair shaft. The pigment, generically known as melanin, is much alike in various organs of the same individual, in different individuals of the same race, and in different races of man; but there are indications that it may represent a complex of related forms differing by slight chemical variations.

The main function of pigmentation is a protection of the skin and the eyes against those rays of the sun which would be harmful to the organism; in addition to which pigment may possibly serve also as an accessory means for the elimination from the system of certain substances that result from the metabolism in the cells. A complete lack of pigmentation, as abnormally present in full human albinos, is accompanied by weakness of the eyes as well as great irritability of the skin.

The acquisition of pigmentation in man is of ancient ancestral origin. According to various indications, early man, up to at least the middle of the Palaeolithic period, was brown in color, with hazel to dark-brown eyes and reddish-brown to black hair. He was a product of the Tropics or semitropics and could not have developed there without adequate pigmentation.

Before the middle of the glacial period this early man reached western Europe, which according to many indications became the cradle of his further differentiation. It was primarily from Europe that he spread into other parts of the world, and it was from western Europe that he eventually followed the final recession of the ice northward, until he peopled what are now Denmark, northern Germany, and the Scandinavian Peninsula.

These regions concern us particularly in this connection. Under the peculiar postglacial climatic and environmental conditions of northwesternmost Europe, combining in all probability considerable cold, damp, and cloudiness or mists with a diminished amount of light, and the effects of these conditions on man's clothing, housing, and habits in general, the protective pigmentation of those who lived there became to a large degree unnecessary, and as organisms will not tolerate for long anything that has become useless, the pigmentation of the northerners was reduced. Gradually or by mutations man grew lighter in these lands until he came to constitute a blond "race". He has lost so much pigment that his skin has

become "white", his eyes blue, his hair light, ranging from light brown, yellow, or golden, to almost colorless. In the more central parts of Europe the depigmentation was less effective, and the result is the intermediary "Alpine" or "Kelto-Slavic" type; while in southern Europe, Asia Minor, and northern Africa it was still less, leaving us the swarthy to brown, dark-eyed and black-haired Mediterraneans. It may be noted, however, that, except in full albinism, even the whitest skin, the lightest blue eye, and the lightest hair still retain some of the old pigmentation. The blue eye in particular is not blue because of any new form of coloration but because the remaining pigment is limited to the posteriormost cells of the iris, the result of which is that the eye appears more or less blue on refraction; but, viewed from behind, the iris is not blue.

EFFECTS OF MIXTURE.

Through long residence in their respective regions, and inbreeding, the three main types of pigmentation, or rather depigmentation, in Europe have become fairly fixed, so much so that even a prolonged residence elsewhere, such as that of some offshoots of the blond type in parts of the Mediterranean region and that of the dark Jew or offshoot of the Mediterraneans in northern Europe, has not been potent enough fully to efface either the blondness or darkness, though there has not been a complete preservation. There are, however, no sharp lines of demarcation, no break of continuity, between the blond and medium, or the latter and the dark type; even where purest they pass on the boundaries imperceptibly into each other.

But due to original individual variation in the grade of the depigmentation, and to the great mixings of the European peoples before and especially within historic times, a large majority of the people of every larger country, and even district, retain some of the old differences in these respects or have lost more or less their one-time purity. A great majority of the present population of Europe are mixed bloods—within the limits of the white race—and the mixtures have played havoc with pigmentation.

Yet the effect of the mixings in relation to pigmentation has been simple enough, consisting merely of an addition by the darker parent of so much melanin—or more strictly of so much more tendency to form melanin—to the progeny. In the blonds this tendency has been largely lost; in the mediums and darks partly to largely preserved; in the mixtures of darker strains with lighter it becomes more or less restored, and in consequence the progeny will show in varying degrees a darker pigmentation than the light parent. By admixture with a darker line the blond strain returns more or less toward its ancestral pigmented condition. Whether any of the first or second

generation of the mixed progeny may, through a Mendelian form of heredity, be born once more pure light, medium, or dark, as were their parents or grandparents, is not yet definitely known, but the plainly evident results of the mixture between different types of pigmentation is a large variety of intermediaries.

The effects of such mixtures are not manifested in the same way in all the involved parts. The skin-hair-eye pigmentation behaves in a large measure as a unit, but in interbreeding not infrequently this complex becomes more or less dissociated and its components enter into differing combinations with the pigmentation factors provided by the other germ cell. The skin, hair, and eyes show somewhat different tendencies in these directions.

In the skin the usual result of a mixture of two types of color is a uniform change, but the grade of this change may show considerable differences in different members of the resulting family. There are, however, also cases of irregular "blends." These may be witnessed occasionally in the admixtures of the white with the negro, and, probably more frequently than we are generally aware of, in the mixtures of darks and lights among the white people. The darker strain manifests itself in the form of more or less marked irregular areas or patches, or in larger or smaller "freckles." Permanent freckles have much more significance than they have hitherto received, and even passing freckles may occasionally have a phylogenetic rather than mere ontogenetic or casual significance. The characteristic freckled "Scotch skin" is much more probably a record of admixture of a darker with a light type in the past, than a sun effect, or a meaningless individual, or tribal peculiarity.

The hair in mixture behaves much like the skin. Generally the result is a "blend," or rather increased pigmentation more or less over that of the lighter parent. But not infrequently in mixed progeny with the lighter shades of hair, particularly in females where due to the length of the hair the conditions may be more easily appreciated, there may be detected strands of darker or lighter hair than the majority. An imperfect blend seems also to exist in some of the "sandy" or "rusty" reds. Individual tufts or locks of black or white hair are anomalies, though they may run in families.

The organs in which the most varied and interesting conditions result in consequence of mixture are, however, the eyes. The original human eye was probably hazel (or medium brown) to dark brown. All the primates, all the colored races of man, and a considerable proportion as yet of the whites have brown eyes. Such eyes in earlier times were doubtless associated with dark hair as well as a darker skin. But under the already discussed environmental conditions of northwestern Europe, acting through thousands of years, the protective brown pigment, no longer needed, was eliminated until it

disappeared from the eyes, nearly disappeared from the skin, and was greatly diminished in the hair. The result so far as the visual organ was concerned was the blue eye, which became fixed by heredity. The blue eye, as already noted, is not an eye wholly without pigment—that condition is present only in the eye of the full albino; neither is it an eye with any special pigment. But whatever pigment is present in the blue eye is located only in the posterior columnar epithelium cells of the iris, whereas in gray, brown, and the so-called black eyes pigment is found also in branching connective tissue cells interspersed between the bundles of connective tissue that form the substance or stroma of the iris, and even in the endothelial cells on the front of the iris.

If an unmixed blue-eyed person marries one with brown eyes, the result, as shown in the color of the eyes of the progeny, may be one of several distinct conditions. In a small number of cases of such progeny, taken at large, it will be seen that the brown pigment owed to the darker mate has been distributed uniformly throughout the iris, and, according to its quantity, instead of a blue eye we shall have "grays," possibly some "greens," and light browns, the latter of which in a strong light may show a greenish tinge. But in the large majority of cases the distribution of the brown pigment in the iris will be more or less localized, and we shall have a bluish (never perfectly blue), grayish, or greenish eye with a brown ring or area about the pupil, or brown specks or spots scattered over the iris, with a closer aggregation about the pupil. These cases constitute the large category of "mixed" eyes which are encountered in the central and north European peoples of the present time, and which are very common among Americans.

CLASSIFICATION.

A detailed investigation on pigmentation in a highly complex population, such as that of the United States, offers, due to the conditions enumerated above, some difficulties. There are a large number of shades in the color of the skin and hair which pass into each other without any lines of demarcation, and in the case of the eyes there are numerous mixtures that are not always easy of characterization. A correct appreciation and recording of the true conditions requires good eyesight in the observer, proper light, distance, and exposure (skin) in examination, a careful effort at distinguishing the true conditions, and the simplest possible thoroughly understood scheme of classification. Fortunately extreme details, except in some special researches, are not necessary, and the many shades met with may be grouped into a few categories that are not only sufficient for ordinary scientific purposes, but are also readily intelligible to the nonscientific man.

The most practical classification for white people of the American type as found by the writer, both through considerable experience in examination as well as in the analysis of the obtained records, and one which was therefore used throughout in these studies, is as follows:

PIGMENTATION.

SKIN.

<i>Light</i> (blond, pale-rosy).	<i>Medium</i> (all between light and dark).	<i>Dark</i> (swarthy, dusky).
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HAIR.

<i>Lights proper</i> (blond, yellow and golden, light brown, near blond).	<i>Light brown</i> (not blond).	<i>Medium</i> (medium brown, medium dark).	<i>Dark</i> (dark brown, dark, near black).	<i>Black.</i>	<i>Red</i> (sandy light, brick, salmon, dark, or chestnut red).
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EYES.

<i>Pure lights</i> , blue (pure, light, medium, deep); green (pure); gray (pure).	<i>Intermediates, mixed</i> (brown spots, splotches, ring, or tinge, in lights; in browns, plain tinge of gray or greenish).	<i>Pure browns</i> (light, medium, dark).
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In general the pigmentation of the parts examined shows considerable conformity. A light skin will be associated with blond or yellow hair and light to medium blue or greenish eyes; red hair goes generally with a light to pale rosy skin and a light to medium blue or greenish or mixed eye; and a dark brown eye is invariably associated with dark to black hair while the skin will range from slightly brunet to dark. As a rule also the unmixed medium and dark types breed true, the lights producing lights and the darks, darks, though the range of exact shading in each is fairly extended. But those with medium pigmentation seem less stable and harmonious, and the usually large category of mixtures presents frequent smaller or greater disharmonies and irregularities.

COLOR OF SKIN.

The observations on the skin in the present studies, extended to 200 "Old American" males and 250 females without selection. The gross results are as follows:⁵

⁵ It is self-evident that noninstrumental observations such as these, however carefully made, can not claim mathematical precision, and would probably differ slightly from observer to observer; but these differences, with equally instructed students, could not be great enough materially to affect the general results.

Color of skin.

Skin.	Males (200).		Females (250).	
	Number of subjects.	Per cent.	Number of subjects.	Per cent.
Light (perceptibly lighter than medium).....	1	.5	13	5.2
Medium.....	135	67.5	188	75.2
Swarthy (perceptibly darker than medium).....	55	27.5	42	16.8
"Scotch" (freckly), otherwise medium.....	9	4.5	7	2.8

The above figures show that in a little over seven-tenths of the cases in men and in over three-fourths of the women the color of the skin of the Old Americans may be classed as medium; that, particularly in the males, there is in health but a small proportion of lights, but that a very appreciable minority possess skin that, while far from really dark, is perceptibly "swarthier" or darker than the medium.

There is throughout the series a somewhat greater inclination toward pigmentation of the skin among the males than among the females. This to some extent is probably connected with more exposure among the males, but it does not seem to be due to this alone. The whole showing is rather noteworthy, for, as will be seen presently, it is not paralleled by the pigmentation of other features.

A study of the correlation of the skin color with that of the hair and eyes gives results that are very interesting. There were recorded one "light" skinned male and thirteen females, and the corresponding hair and eye colors were:

Correlation of color of hair and eyes with the color of the skin in Old Americans.

LIGHT SKIN.

Number.	Skin perceptibly lighter than medium.	Hair.			Eyes.		
		Blonds.	Reds.	Light brown.	Light blue.	Medium blue.	Grayish or greenish blue.
1	Male.....			1	1		
13	Females.....	6	4	3	3	5	5
14	Subjects, per cent.....	43	28.5	28.5	25.5	35.7	35.7

All the subjects with light skin are, it is seen, blonds or near blonds, with a few reds. There appears therefore to be a positive correlation between a lighter than ordinary skin and light hair and eyes. Wherever there is a subpigmentation of the skin, there is also in our subjects a feeble pigmentation of the eyes and hair. But the rule does

not work both ways—subjects with light hair and eyes do not always or even very often have also a lighter than medium epidermis.

On the other side of the "medium" we have the more or less swarthy, dusky, or faintly tawny skins, and the correlation of hair and eyes with these discloses some curious conditions.

Correlation of color of hair and eyes with the color of the skin in Old Americans.

DARKER SKIN.

Num- ber.	Skin perceptibly darker than medium.	Hair.				Eyes.			
		Lights.		Me- dium.	Dark to black.	Reds.	Browns.		
		Blond.	Light brown.				Lights (blue, gray, green- ish, mixed).	Light brown.	Me- dium. brown.
55	Males.....		(2)	(16)	(37)		¹ (34)	(7)	(12)
			3.6	29.1	67.3		61.8	12.7	21.8
42	Females.....		(1)	(8)	(33)		¹ (21)	(3)	(13)
			2.4	19	78.6		50	7.1	31
97	Subjects, per cent.....		3.1	24.7	72.2		56.7	10.3	25.8

¹ Mostly "mixed" (blue or greenish or grayish with more or less marked traces of brown).

The above shows that in the darker persons there exists a very marked correlation between the color of the skin and that of the hair. There are no "blonds" in the men or women with darker skins and unexpectedly also no "reds," which points to a rather close relation of these shades; and there is a very large proportion of darks to black. Also, throughout, there is an evident tendency toward more darkness of hair and eyes in the females than in the males, which, however, as will be shown below, does not apply alone to this class of cases.

As to the eyes, the correlation of their color with that of the skin is plainly less than with the hair. A good proportion of both men and women with a darker skin and dark hair have blue, greenish, gray, and especially mixed eyes; but there is also a considerable proportion of browns, much above that in the Old Americans at large. The women show again a greater tendency in this direction—they have less "lights" and light browns, but decidedly and progressively more medium and dark browns. Why this should be so is not yet quite clear, but we shall return to the phenomenon, which seems to be generalized among all whites, on another occasion.

The above correlations between brunet skin and the color of the hair and eyes may be shown still more clearly by comparing the percental representation of the different classes of shades of the hair and eyes in those with swarthy skins to the whole number of subjects in our series:

Color of hair and eyes in subjects with skin perceptibly darker than medium compared with that in the series at large.

[Percental relation to proportion in the whole series.]

	Hair.					Eyes.			
	Blonds.	Reds.	Light brown (not blond).	Medium.	Dark to black.	Blue, green, gray, mixed.	Light brown.	Medium brown.	Dark brown.
Males.....			22	58	279	74	310	225	124
Females.....			24	44	262	65	203	209	243

Among those with darker skins there are, in respect to hair, no blonds or reds, only a little over one-fifth as many light browns, and approximately one-half as many medium browns as in the Old Americans taken as a whole, but nearly three times as many darks to blacks. As to eyes, the darker-skinned show one-fourth to one-third less lights but more than twice as many browns, two to three times as many light browns, over twice as many mediums, and over once to twice and a half as many darks. A greater tendency to eye pigmentation is once more apparent here in the women.

The meaning of these conditions tends to be that a normally darker skin in the American and doubtless other whites is generally an expression of not a localized but a systemic tendency toward darker pigmentation, and as such is probably of phylogenetic rather than ontogenetic significance; that it is, in other words, a survival of a darker ancestry rather than an individual peculiarity. Just how much more or less of the darker skins there are in the Old Americans than among other whites we shall only be able to tell from similar studies among these other groups.

The "Scotch skin" is a medium white skin with numerous light and rather large and irregular "freckles" on the exposed parts. On the face these "freckles" extend to the forehead. It is highly characteristic of a proportion of persons of Scotch derivation and that among the Old as well as recent Americans. The subject deserves a detailed study of its own. As already mentioned, there is a strong indication that these "freckles" are merely the remnants of a darker-skinned strain admixed in the dim past into the Scotch people.

THE HAIR.

The records on pigmentation of the hair are much more numerous and comprehensive than those on the skin. They apply to 1,009 men and 914 women.

The method, based on considerable experience and preliminary work, was to subdivide the large range of colors into as few as possible definite classes, and then to use common sense, with good indirect

light, plenty of time, and due care, in determining the shade. In general this method is preferable to that of comparing the hair with given standards, for that takes longer and among such a mixed population as ours we would never have enough standards. It is true that it is not easy in such a visual method to get rid of all personal equation, but the amount of such an equation may be very much reduced and be rendered practically insignificant by due instruction or understanding of the subject, with practice. The final classification of the shades is not arbitrary. We begin with the safe units of "black," decidedly "light," and unmistakably red. This leaves a large category of intermediate grades, all of which fall, however, into three subdivisions, namely, light brown (not blond), medium (or "medium brown"), and dark (or "dark brown"). A large majority of cases will readily and unmistakably be placed in one or another of these classes by every properly instructed observer. This will leave, as possible sources of error, only the transitional shades, for there are between none of the colors any definite lines of demarcation. These cases, with a careful student, will amount to approximately 10 per cent with the blonds, 20 per cent with the light browns (not blond), mediums, darks, and reds, and 5 per cent with the blacks. When we add to this that by the law of chance, other things (such as the training of the observers, etc.) being equal, as many of the "uncertains" in each category will be recorded right as wrong, and that those recorded wrong in one class will be counterbalanced by the wrongs of the next, it may be seen that unless there is a lack of due instruction, negligence, or the development of some special bias on the part of an observer, his records on any large series of individuals will be substantially correct and comparable with those of all other similarly instructed and careful workers. That this is so may be shown in our series in Virginia. In a camp of the U. S. Corps of Engineers, near Charlottesville, after due initiation the work was left in the hands of Dr. Robert Bennett Bean, of the University of Virginia. The results, except for a slight difference which developed in recording the eye colors, were practically identical with those of the author as far as the latter applied to the same territory.

The study of hair color among the Old Americans fully confirms previous observations on the change in the color of the hair with age. Except in those with the darkest shades the hair in general shows from infancy on to adult life and in many cases even through a part of the adult life, a progressive darkening. The lightest hair in an infant may thus eventually become light, medium, or even fairly dark-brown—though not black. Even the red hair darkens or loses its purity. The golden also is unstable. A small series of near-adults found by the writer among the teachers shows, as will be shown later

on, a very perceptibly higher grade of lightness than that of the fully adult of the same class. In some persons the darkening of the hair seems to progress until the time when the first traces of graying (in individual hairs) commences. This progressive darkening of the hair has been observed in all white people with hair lighter than black. Its causes are not yet well understood. It means, of course, a progressively greater production of the hair pigment, but whether this is due to environmental stimuli, metabolic changes, or phylogenetic influence, is not as yet determined. There are decided individual variations in this respect, and possibly also sexual, locality, and other differences. The whole subject deserves a separate, deep-going investigation.

Our records on the distribution of hair color among the Old Americans, as finally tabulated, are as follows:

Old Americans: Color of hair.

	Lights proper.	Light brown (not blond).	Medium (medium brown).	Darks (dark, dark brown, near black).	Black.	Reds.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Males (1,009).....	5.3	16	50	25	1.1	2.6
Females (914).....	6.9	14.2	42.9	29.8	1.3	4.9

These figures are striking in more than one respect. Over three-fourths of the adult Old Americans have hair ranging from medium to dark and black, while but one in 14.5 among the females and one in near 16 among the males is in hair truly blond. The females, as contrasted with the males, show a few more blonds and more reds, but also more darks, while the males give a predominance of the lighter and medium shades of brown.* The females show the greater diversity.

An even closer insight into the conditions is, however, possible. The following data give us the more detailed colors:

Old Americans: Color of hair, details.

	Lights proper.			Light brown (not blond).	Medium.	Dark.	Black.	Reds.
	Blond.	Golden or yellow.	Light brown (near blond).					
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Males.....	1.2	0.6	3.5	16	50	25	1.1	2.6
Females.....	.9	1.6	4.4	14.2	42.9	29.8	1.3	4.9

* It goes without saying that all possible care was exercised not to include any cases of hair changed artificially. Fortunately this is not frequent in this class of people, except perhaps among some of the older persons where the object is to mask grayness and simulate the natural shade.

The golden and yellow among the females are seen to be more than twice, the near-blonds once and a half, as frequent as in the males. The males, as seen before, predominate in the submedium and medium brown. In the darker shades the females have a larger representation than the males, and this domination, as will be seen later on, is of significance. It may also be stated in this connection that the reds in the females are mostly the more or less golden reds and again the darker reds.

All the above establishes the facts that: (1) The Old Americans are, so far as hair color is concerned, only exceptionally blond, but commonly medium to brnnet; and that the females show a greater proportion of golden, near-blonds, and reds, but also of dark browns and blacks, than the males. The males are more intermediate. Possibly there is in the females a clearer show of varied ancestral conditions, while the males show greater blend.

Tested by subdivisions of 100 or more, the above data hold fairly good, so that they may probably be regarded as practically a true expression of the conditions among the territorially mixed Old Americans in the eastern half of the United States. But in localities where some definite group of immigrants has settled, such for example as the Scotch, Pennsylvania Dutch, etc., the conditions will differ in harmony with the original pigmentation of the group. The ancestral influence appears everywhere to be very tenacious.

The above results indicate that blondness is not characteristic of the Old Americans. There is in addition but a modest proportion of reds and very few true blacks. Half of the people are medium, three-quarters are medium to dark- and black-haired. The affinity of the Old Americans with the Nordic blonds is seen from this to be rather secondary, unless substantial changes in the direction of greater pigmentation have been realized in the Americans since their sojourn on this continent—which, however, as will be seen later, is contradicted by facts.

The records on the two sexes show, it was seen, interesting differences, though the total amount of pigmentation in the two sexes is about the same. The women evidently preserve better the different ancestral conditions from which the mixture represented now by the Old Americans arose, while the men show more fusion, more blend. Similar facts, including the preponderance of the darker shades in the females, have been observed elsewhere. The English observers in particular have shown that the women of Great Britain tend to be darker than the men. From Beddow's data, Parsons⁷ found that among the English the females were, according to regions, darker haired than the men by from 0.6 to 6.5 per cent. Fleure and James⁸

⁷ J. Anthropol. Inst., 1920, I., 166-167. See also Beddow, J.—*Anthropological History of Europe*, 1912 ed., 98.

⁸ J. Anthropol. Inst., 1916, XLVI., 49.

found similar conditions—that is, a greater predominance of darks among the females than among the males—in Wales; and Gray with Tocher⁹ in Scotland. The latter have also shown further by their studies on Scotch children¹⁰ that the greater darkening of the females is a postnatal, or rather postinfantile, phenomenon.

For purposes of sexual as well as groupal or racial comparison, it would be very convenient if it were possible to reduce the different classes of hair color to approximate numerical values. It seems well worth while to make an attempt in this direction. Let us take pigmentless hair as 0, black hair as 100, and medium hair as 50. It will then be reasonable to assign to the "Light-brown" (not blond) class the mean value of 25 and to the light or blond (with golden, yellow, and light-brown near blond) that of 12.5; while the "Darks" will be 75. For red hair, the most difficult to gauge, we may perhaps assume the mean value of 35. These values, which are not as arbitrary as they might seem, will be seen better in a little table:

Assumed values of hair colors.

Lights proper (blonds or near)-----	12.5
Light brown (not blond)-----	25
Medium-----	50
Dark-----	75
Black-----	100
Red-----	35

If now the records on hair pigmentation be presented in these values, we obtain the following:

Old Americans: Units of hair pigmentation.

[Per 1,000 subjects.]

Shade	Males.	Females.
Lights proper.....	662	862
Light brown (not blond).....	4,025	3,550
Medium.....	25,000	21,450
Dark.....	18,750	22,350
Black.....	1,100	1,300
Reds.....	910	1,715
	50,447	51,227

Males : Females :: 100 : 101.5.

The females are on the whole approximately 1.5 per cent darker than the males. This proportion will naturally differ with region as the actual records differ, but the female always shows a greater total.

⁹ J. Anthropol. Inst., 1900, XXX, 109.

¹⁰ *Ibid.*, 115.

REGIONAL DIFFERENCES.

Attention was given from the start of the studies to possible indication of regional differences in pigmentation, especially between the North and the South; but nothing striking or definite became manifest in this direction. What differences do exist became apparent only after the data were reduced to percentages. The results are shown in the following table:

Regional distribution of hair color in the Old Americans.

MALES.

Region.	Lights (lights proper and light brown).	Medium.	Darks (dark to black).	Reds.
New England ¹ (63).....	26.1	55.4	² 16.9	1.5
Middle East and mixed (449).....	22.4	45.2	29.6	2.7
South (District of Columbia and southward) (369).....	22.3	48	27.1	2.7
Appalachians (Tennessee and neighboring) (126).....	12.7	69.8	15.1	2.4

FEMALES

New England (41).....	39	34.1	² 26.8	.....
East and mixed (339).....	21	37.2	36.3	5.6
South (534).....	19.8	47.2	28.1	4.9

BOTH SEXES.

	Blonds and mod- erately light.	Medium.	Dark (to black).	Medium and dark.	Red.
New England (106).....	32.6	44.8	21.9	(66.7)	0.7
Middle east and mixed (788).....	21.7	41.3	32.9	(74.2)	4.1
South (903).....	21.1	47.6	27.6	(75.2)	3.7

¹ All American ancestors of the subject lived in the regions here given, not merely the individual recorded

² No blacks.

The regional differences in hair color, it can be seen from the above figures, are not very material, yet there are differences, and in a measure, as to between North and South, they bear out the common notion. In both sexes among the "Yankees" there is a larger proportion of lights and a somewhat smaller percentage of darks than in the South. The hair among the Old Americans of the South may therefore be said to be less frequently blond and somewhat more frequently dark than that of the same class of the population in the New England region. But the Old Americans of the Middle East and of mixed-State parentage agree very closely with those of farther South, showing, if anything, even a good trace more of darks, though if we take the mediums and darks together the proportions

are almost identical. In all the regions it is noticeable the females present a larger proportion of darks than the males, indicating a deep-rooted tendency in this direction. In the New England States there appear also more female than male blonds and less intermediates. The females show less intermediates throughout the series.

A very interesting locality group is that of the more northern Appalachian mountaineers. They show the least lights as well as darks and by far the most intermediates of any of the groups. This is in all probability the result of a more thorough intermixture, due to interbreeding. The mountaineer, as long as he remains in the mountains, marries almost invariably in the mountains. The group affords a good indication of what would very likely eventually take place in the whole body of Old Americans were there no mixture from outside of their own circles.

Our conclusions may be summarized in the statement that the ordinary conception of the southern Americans being darker than the "Yankees" or New Englanders is sustained to but a moderate extent; that there is no appreciable difference, as relates to hair color, between the southern and Old Americans at large, but that more isolated groups in the South and possibly also in the North may be expected to show more or less exceptional conditions, according to ancestry and grade of intermixture or inbreeding.

RED HAIR.

The subject of red hair, like that of age changes in hair color, is not yet fully understood and needs a thorough reinvestigation. The two prevailing theories are first "that it is a variant of fair hair because it so often accompanies a freckled skin and light eyes; the other that it shows a mixture between a light and a dark race" (Parsons, *o. c.*, 182). The English records "seem to help both theories * * * Scotland and the north of England are the fairest parts of the kingdom, and it is there that red hair is most marked, but it is also well marked in Wales and in parts of Ireland, especially Kerry, where the nigrescence is very high."

From the English records it would appear that there is no regular sex difference in the proportion of redness. In 66 locality groups (Beddow's observations), 30 show a larger percentage of reds in the females, 32 in males, and in 4 the proportion was equal. The whole group of Beddow's males gives a red hair percentage of 4.4, the equally large group of females 4.9. From the same data Parsons finds that "red hair is more common in the upper than in the lower classes," to which he adds (*o. c.*, 182) that according to his own observations not only is red hair commoner in the upper classes, but that these classes have also an altogether lower index of nigrescence; in other words, are less pigmented than the lower.

In the course of the study on the Old Americans the impression grew that the category of "red hair" is not wholly homogeneous, and that it probably includes more than one related condition. There are "reds" in which the whole system participates in the phenomenon. The eyes are pale, light blue, or greenish, the skin is akin to the rosy skin of the albino, the breast areola is devoid of pigment, the mucous membranes are light red. Also these individuals are generally believed to differ more or less mentally, as well as in their predispositions to certain ailments, from the average of the population. And there are other "reds," generally of the darker shades in whom the rest of the system does not participate, or participates but little in the condition, is not peculiar, in other words, to any marked extent. It may be that the differences are merely those of degree; we shall not know until the subject is exhaustively investigated by itself. A study of the blood may one day help to clear matters.

Red hair, or at least some of it, also changes with age. Some such hair grows nearer to brown, loses in luster and beauty and loses the gold of the red: while some simply darkens.

A relation of red hair to the brown is very evident. Most brown hair in certain light shows a more or less marked trace of red, and the moustache of brown-haired men is generally more or less "rusty," that is, nearer red. A relation to the blonds is not apparent, except perhaps through the golden red. It is a golden red which accompanies all shades of color down to dark brown. On the whole, red hair seems to imply a partial loss of pigment from the hair, a loss limited possibly to the outer layers of hair cells. It is a phase of depigmentation, not a variant of blondness; and the red pigment, if it exists as such, appears to be only a variant of the ordinary brown pigment.

The relation of red hair to the color of the eyes will be dealt with later. The relation of red hair frequency to social status, as believed to exist in England, did not become apparent among the Old Americans where there is little class distinction. Our highest group socially (on the whole) gave for the men the frequency of 2.2, our lowest 2.0 per cent of red hair: while what could be taken as an intermediate group showed 3.0 per cent. Geographically, the least red hair (men but 1 case, women 0) occurs in our series of the New England States; the most (men 2.7, women 5.6 per cent) in the Middle Eastern States and in those of mixed parentage from more than one State.

Eye colors in the red-haired.—An interesting inquiry was that into the association of eye colors with red hair. It is common knowledge that red hair is generally associated with light eyes, yet the matter seems never to have been subjected to a rigorous test. Our records disclose the following conditions:

Eye color in individuals with red hair.

BOTH SEXES.

Blue.			Greenish.	Grayish.	Mixed.	Brown.		
Light.	Medium.	Deep.				Light.	Medium.	Dark.
% 6.2	% 16.9	%	% 7.7	% 6.2	% 56.9	%	% 6.2	%
23.1								
Lights, 37					Mixed, 57	Browns, 6		

A little over one-third of the red-haired Old Americans have light eyes. A little less than a half of these (46 per cent of the group or 17 per cent of the whole) are "light eyes—light reds," and to somewhere near that extent only may we assume red hairedness to be directly associated with blondness. In the rest of the cases with pure light eyes the hair was medium to brownish- or chestnut-red.

A large proportion of the eyes in the red haired are mixed. In the whole series studied the proportion of mixed eyes was approximately 48 per cent; in the red haired it is 57 per cent, a plain excess for the latter. This excess, as well as the whole proportion of mixed eyes in the red haired, points to the conclusion that red hairedness is strongly associated with mixture of blonds and brunets; that, in other words, it represents partial depigmentation or repigmentation.

In a small per cent of our cases red hair was associated with eyes that were pure medium brown. The hair ranged in these individuals from light-red and salmon-red to brown-red and chestnut-red. As the brown eye is believed to be dominant over the lights in mixtures, the mixtures of types in these cases may have remained occluded; but a partial depigmentation of the hair from any other cause might possibly have been sufficient. We should scarcely be justified, in other words, without much further inquiry into the subject, in regarding red hair in the progeny of brunet parents as an absolute proof of admixture into the family of either a red or blond haired outsider.

The conclusions concerning red hair may be briefly summarized as follows:

(1) Red hair appears to be merely a form of depigmentation (or partial repigmentation).

(2) In traces and minor degrees it is a far more common condition than generally appreciated.

(3) In a large majority of cases it is connected with the mixture of light with darker types of individuals.

(4) In a minority of cases it may probably exist without mixture as a variation in the direction of depigmentation (or partial repigmentation).

(5) There are red-haired individuals in whom the depigmentation involves the whole system, approaching more or less albinism and an abnormal condition.

(6) There is no line of demarkation between red hair and golden on one side and red hair and the different shades of brown on the other.

ANOMALIES OF HAIR PIGMENTATION.

Anomalies of hair pigmentation relate to uniformity in color and premature or delayed grayness. But little in these respects was noticed among the Old Americans, if we disregard slight to moderate irregularities in shading (lighter or darker strands).

Two individuals, however, one male and one female, showed different colored tufts (or locks) of hair. The female had a white lock in dark hair above the forehead; the male a black tuft in otherwise uniform medium hair above the fore part of the right temporal region. In one female 45 years old most of the hair on the right side was medium brown, while the whole left side was (naturally) perceptibly darker.

THE EYES.

To properly gauge the eye color is a fairly simple matter in some groups of the white race, such as the pure Nordics or the Mediterraneanans, but it becomes a difficult task in mixed strains, such as that of the English and especially the Americans.

To approach the subject properly we should be clear to start with on the elementary question as to what is eye color. The many shades of eyes to be met with, as with the hair, do not represent so many different pigments but only so many grades and varieties of pigmentation and depigmentation. The eye pigment, like that in the skin and doubtless also in the hair, is there for protection, and though it may not be strictly simple or homogeneous it behaves essentially as one pigment which is distributed in small granules in the lining and certain interstitial cells of the iris. The color of the iris is a reflection of light according to the quantity, density, and distribution of the pigment granules. If these granules are in considerable quantity and distributed throughout the endothelial, interstitial, and even epithelial cells of the iris, the eye is brown to "black," the shade differing with the total quantity and density of the granules. With the maximum quantity the eye is black, as in some negroes; on the other hand, as the quantity of the pigment decreases we have gradually a lighter and lighter shade of brown until this passes into light brown, then grayish or greenish brown, then bluish or greenish gray, and finally, when no pigment remains in either the anterior lining or the interstitial cells of the iris, with but little in the endothelium, the eye is blue.

As in the skin and hair, so here again there are no lines of demarcation between the various shades, and we must make a somewhat arbitrary classification. In this we may recognize to start with two great groups, the pure eyes and the mixed. The pure in their turn are capable of three subdivisions, the browns, the blues, and the lights other than blue (gray, greenish); and the browns and blues are further subdivisible each into the dark (or deep), medium and light. Intermediary tinges occur appearing different under varying conditions of light, health, and mental state, and can be classified only with difficulty.

The "mixed" eye is strictly speaking a misnomer. It does not mean an eye with a mixture of any two distinct pigments, but an eye, resulting from a mixture of a brown-eyed with a lighter parent, in which the parental conditions are not well blended. If the eyes of the parents are different, the eyes of some of the progeny may show a darker or lighter blend of the parental colors; the eyes of some may show one or the other parental shade dominating with the other in recession; but the eyes of most of the children will bear traces of the mixture in an unequal distribution of the pigment derived from the darker parent.¹¹ It is these last eyes alone that the observer can designate as "mixed."

The "mixtures" are of many kinds, but they are all characterized by some imperfection in the distribution of the brown. This may occur as a narrower or broader ring about the pupil; as a greater or lesser dispersion of brown spots, with an aggregation about the pupil; in the form of brown patches or stains of color over the iris, with lighter regions; and rarely in the form of a single brown segment radiating from the pupil to the periphery of the iris.

From the above it will be seen that the only rational classification of eye color can be about as follows:

EYE COLORS.	
(Largely)	
Depigmented, pure.....	Blues.....
	Gray.
	Greenish.
	Grayish-blue.
	Greenish-blue.
Pigmented.....	Brown.....
	Black, or near black.
Mixed	Light brown...
	Gray.....
	Greenish or blue
	{Light.
	{Medium.
	{Deep.
	{Light.
	{Medium.
	{Dark.
	{With rings, spots, patches, areas,
	{stains, or segments of brown.

¹¹ The laws of heredity in this connection are still under investigation. See Davenport (C. B.)—Heredity of Eye-Color in Man. *Science*, 1907, XXVI, 589; Hurst (C. C.)—On the Inheritance of Eye-Color in Man. *Proc. R. Soc.*, 1908, 80 S; Boas (Helen M.)—Inheritance of Eye-Color in Man. *Am. J. Phys. Anthropol.*, 1919, II, 15-20.

All records on eye color, however carefully made, necessarily bear the following imperfections: A small number of the apparently pure light browns, and other-than-blue lights, will belong to the category of only apparently and unstably (in relation to progeny) pures; they are mixeds in which the mixture is not clearly perceivable. A small proportion of the medium browns will be in the same category. A superficial observation in addition will inevitably result in classing many of the mixeds as pures. The classes which are most free from error will be the pure blues and the darker browns, in which it will merely be a question of classification errors along the boundaries.

There have been many former attempts at a satisfactory classification of eye color, and several "standards" have been made by which to record these colors. Being largely empirical, however, none of them, neither classifications nor standards, are fully satisfactory. In the present studies reliance was placed on the above analysis of the colors, on due regulations of the procedure, on large practice, and on constant care. All eyes were examined in clear light, at the distance of best vision, the "reading distance." The use of artificial standards, after sufficient expertness was acquired, was found unnecessary and hindering rather than facilitating the examination.

With all the above regulations and precautions it is certain that the results on eye color here recorded are still imperfect; though they are probably as near correct as they can be made under present conditions.

The number of records on eye color among the Old Americans is the same as that on the hair, namely, 1,009 males and 914 females; and the total data show the following results:

Old Americans: Color of eyes.

	Pure lights.	Mixed.	Pure brown.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Males (1,009).....	31	52.5	16.5
Females (914).....	24.1	55.9	20

More than half of the eyes among the Old Americans are mixed, in general, a light of some sort with specks, ring or other plain traces of brown; approximately one-third in males and one-fourth in females are pure lights, and one-sixth in males with one-fifth in females are pure browns. The females have less pure lights and more browns, showing again the tendency towards somewhat greater pigmentation.

The above data contrast in an interesting way with those on hair.

Old Americans: Contrast of hair and eye color.

	Hair.			Eyes.		
	Lights. ¹	Medium.	Darks.	Pure lights	Mixed.	Pure browns.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Males.....	22.2	50.8	27	31	52.5	16.5
Females.....	22.7	44.6	32.7	24.1	55.9	20

¹ To each category is added one-third of the reds

There is seen to exist a marked general correspondence of lights with lights, medium hair with mixed eyes, and of darks with darks; but already these gross figures show more light eyes than light hair and more dark hair than dark eyes, indicating that on the whole the hair tends towards a greater pigmentation than the eyes. It is known that this tendency, while universal, is particularly noticeable in certain districts or among certain racial groups in Europe. The Irish are a good example.

Additional features of interest so far as the eyes of the Old Americans are concerned, are shown by a more direct classification:

Old Americans: Color of eyes, details.

	Pure lights.					Mixed.	Pure browns.		
	Blues.			Other lights.			Light.	Medium.	Dark.
	Light.	Medium.	Deep.	Greenish-blue and greenish.	Grayish-blue and gray.				
<i>Percent.</i>	<i>Percent.</i>	<i>Percent.</i>	<i>Percent.</i>	<i>Percent.</i>	<i>Percent.</i>	<i>Percent.</i>	<i>Percent.</i>	<i>Percent.</i>	
Males.....	7.9	14.8	1.1	2.2	5	52.5	4.5	9.3	2.7
Females.....	2.9	15.2	1.9	1.4	2.7	55.9	2.2	13.8	4

Light-blue eyes are more than twice as common in the males as in the females; the medium blues are about equal in the two sexes; the deep blues are nearly twice as frequent in the females as in the males. There is therefore a tendency in the males toward the lighter, in the females toward the darker shades of blue. This is in all probability connected with the general tendency of the females toward a greater eye pigmentation, which is shown very plainly by the browns. The females show also less of both the pure greenish and the grayish eyes, which most likely is equally due to the phenomenon just mentioned.

We may well ask in this place just why this tendency toward greater pigmentation in the female hair and eyes should exist. So far as the writer knows, while the fact has been recorded again and

again, no serious attempt has yet been made at showing the reason. Yet there must be reasons, and judging from the generality of the tendency, they are more likely to be of inherited than of environmental nature.

These are the facts that may have a bearing on this question. In the section on skin pigmentation it was seen that the skin of the male is more frequently darker than medium than happens among the females; should this fact be substantiated elsewhere, we would be justified in assuming that the skin in the male takes care on the average of a somewhat larger quantity of the pigment produced in the body, while in the female, should she produce proportionately to her weight as much pigment as man, the surplus would be likely to go into the eyes and hair. In addition, the male discharges a substantial quantum of pigment through his beard, moustache, and greater body hairiness, as well as through the hair of the head, for due to the frequent cuttings a man produces on the average more hair on his head than a female. All this disposes in the male of a considerable amount of the pigment formed in the body, so that if the sexes produced the same or nearly the same amount per pound of active tissue, there would be a surplus of pigment in the female which would inevitably, it seems, affect the pigmentation of both the eyes and the hair. There is no indication that there is any greater production of pigment in the female, but she differs slightly in the manner of its disposition and elimination.

The relative pigmentation of eyes in the two sexes may also, as in the case of hair, be presented in the form of values. If the subject is carefully weighed it will be found that about the following approximate values may be assigned to the different eye colors:

Assumed values of eye colors.

Pure lights:	
Blues—	
Light.....	10
Medium.....	20
Deep.....	25
Greenish.....	15
Gray.....	30
Mixed.....	50
Pure browns:	
Light.....	65
Medium.....	75
Dark.....	85

Arranging our data on this basis, we obtain the following interesting results:

Units of eye pigmentation.

[Per 1,000 subjects]

Shade.	Male.	Female.
Pure lights:		
Blues—		
Light.....	790	290
Medium.....	2,960	3,040
Dark.....	275	475
	4,025	3,805
Greenish and greenish-blue.....	330	210
Gray and grayish-blue.....	1,300	810
	5,855	4,825
Mixed.....	26,250	27,900
Pure browns*		
Light.....	2,925	1,430
Medium.....	6,975	10,350
Dark.....	2,295	3,400
	12,195	15,180
Total.....	44,300	47,905

Eyes—Males : Females :: 100 : 108.1.

Hair—Males : Females :: 100 : 101.5.

A few words only are necessary to supplement the above figures. The pigmentation of the eye among the females in the Old Americans is to that of the males as 108.1 to 100; the female eye in other words is approximately 8 per cent darker. The rest of the differences parallel what has already been shown by the simple percentages. It is interesting to observe that the differences in the eye pigmentation exceed those in the hair. The same phenomenon, as will be seen later, has been observed in England and is probably true elsewhere.

REGIONAL DIFFERENCES.

As with the hair, so with the eyes, the main interest as to regional differences in pigmentation attaches to the question of differences between the north and south. The following table shows these relations:

Regional distribution of eye color in the Old Americans.

Region.	Both sexes together.		
	Pure lights.	Mixed.	Pure browns.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
New England.....	32.8	48	19.2
Middle East and mixed ¹	24.4	55.8	19.3
South.....	30.8	52	17.2
Appalachians (Tennessee and South).....	24.6	62.8	12.6

¹ Part of forbears from Northern, part from Central, or Southern States.

The differences in eye color between the South and the North and between either of these and the Middle States are seen to be only slight, even less than with the hair. There are a few more lights, but also a few more browns among the Yankees than among the Southerners, but the differences are too small to be given any special significance. There is, however, as with the hair, a marked difference shown by the Appalachian mountaineers, among whom there are less pure lights, less pure browns, and a larger proportion of mixed shades. It was seen (p. 459) that precisely the same conditions were observed in this special group in relation to hair colors.

CORRELATION OF EYE AND HAIR COLOR.

In order to make the presentation of the records here dealt with as clear as possible, it will be necessary to show, besides the separate data on hair and eyes, also the associations of conditions. Not every light eye is accompanied with light hair, thereby enabling us to class the subject as blond, nor every dark hair with a dark eye, giving us a well-marked brunet. There are many exceptions in fact to such associations. Conditions were found in brief, as follows:

Old Americans: Correlation in eye and hair pigmentation, both sexes.

(Percentage in round numbers.)

Eyes.	Hair.			
	Lights.	Medium.	Dark.	Reds.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Pure lights.....	37.5	48	12	2.5
Mixed.....	20	50	26	4
Pure browns.....	9.5	43	46	1.5

Persons among the Old Americans with light eyes that show no mixture have in nearly two-fifths of their number also light hair, while in approximately one-half of the cases the hair is medium, and in nearly one-eighth it is dark. Red hair occurs, but in slightly lesser proportion than in the general average.

Those with mixed eyes (lights with more or less marked traces of brown) have light hair in only one-fifth, medium hair in one-half, and dark hair in one-fourth of their number. In respect of both the light and dark hair they start, as might be expected, practically midway between the pure light-eyed and pure brown-eyed series. But they show more mediums, i. e., more blonds, and decidedly more reds. The latter condition demonstrates the close association of, perhaps, as many as half of the cases of red hair with mixture of the lighter and the darker racial elements in the population.

The brown eyed show but a few light haired and these generally of the least blond variety; they have—somewhat less frequently than either the light or the mixed eyed—hair of medium shade; but they show in nearly half the instances dark hair to black. Also they show the least reds and those only in association with the lighter browns of the iris.

Still further insight into these conditions may be obtained if the data are studied with a little more detail:

Old Americans: Correlation of eye and hair pigmentation, details, both sexes.¹

(Percentage in round numbers.)

Eyes.	Hair.		
	Lights.	Medium.	Darks.
Pure lights:			
Blues—	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Light.....	53	43	2.5
Medium.....	35	48	14
Deep.....	25	50	20
Other lights:			
Greenish and greenish-blue.....	31	50	13.5
Gray and grayish-blue.....	34	52.5	13.5
Mixed.....	19.5	50.5	23.5
Pure browns:			
Light.....	22.5	50	27.5
Medium.....	9.5	50	38
Dark.....	4	22.5	73.5

¹ Reds need not be considered in this connection.

The above figures show conditions very clearly. The lighter the blue eye the greater the proportion of light hair and the smaller that of medium and especially dark hair; the deeper the blue, the *less* light, the more medium, and especially the more dark hair. It is plain that there is a direct correlation between the depth of the blue in the iris and the amount of pigment in the hair. This corroborates the view that the pigment in the blue eye is not different from that in the brown eye, but is merely less in quantity and differently deposited. The greenish and grayish eyes, in relation to hair, are much like the medium blue, though showing somewhat more medium hair. Possibly they hide some mixtures. The brown-eyed show the same type of correlation as the blues—the darker the eye the less light, and even medium, and the more dark the hair. Those with dark-brown eyes have no blonds proper, but a few instances of light-brown—not blond—hair and less than one-fourth of medium, but in nearly three-fourths the hair is dark to black.

The above shows that in general the more pigment there is in the eye the more there is also in the hair. There are individual excep-

tions where the hair is lighter than the eyes, but they are not numerous.

ANOMALIES OF EYE PIGMENTATION.

Eye pigmentation shows occasionally interesting anomalies. They are limited to the "mixed" eyes, and seem to be more frequent in females. Also, most of them came from the Southern States, which, however, may be an accident. Those observed were as follows:

Age.	Locality.	Hair	Eyes
Males:			
51.....	Virginia.....	Dark brown.....	Mixed; <i>right</i> shows more brown than <i>left</i> .
43.....	.....do.....	Medium brown.....	<i>Right</i> greenish; <i>left</i> fine medium blue.
43.....	.....do.....	Near black.....	<i>Right</i> gray, traces brown; <i>left</i> , medium brown, traces gray.
23.....	Maryland.....	Medium brown.....	<i>Right</i> medium blue; <i>left</i> medium blue, traces brown.
Females:			
18.....	Virginia.....	Dark brown.....	Mixed, <i>right</i> shows very perceptibly more brown than <i>left</i> .
18.....	Mixed.....	.....do.....	Light blue, slight tinge of brown in <i>left</i> ; more in <i>right</i> .
25.....	Virginia.....	Light brown.....	<i>Right</i> gray; <i>left</i> lighter than <i>right</i> .
30.....	Mixed.....	Medium brown.....	Gray; <i>right</i> traces brown, <i>left</i> pure.
32.....	.....do.....	.....do.....	<i>Right</i> dark brown; <i>left</i> greenish-brown.
34.....	Pennsylvania.....	Dark brown.....	<i>Right</i> pure grayish-blue; <i>left</i> same, but with a speck of brown.
43.....	Virginia.....	Golden brown.....	<i>Right</i> pure deep blue; <i>left</i> same with brown patch.
Triangular wedges or segments:¹			
Females—			
24.....	.....do.....	Medium brown.....	<i>Right</i> pure medium blue; <i>left</i> same but with large segment of yellow brown.
24.....	North Carolina.....	.....do.....	Light greenish; in <i>left</i> a nice wedge or segment of medium brown. ²
30.....	Virginia.....	.....do.....	Medium gray; <i>right</i> shows a clear-cut wedge of medium brown.

¹ Beginning at a point on the inner and diverging toward the outer border of the iris.

² Father has brown, mother light eyes.

No case was observed where one eye was brown and the other light, though one was learned of.

The most interesting of the anomalies are the wedges or segments of brown in one of the otherwise pure and uniform light eyes. They remind one distantly of the eyes of lizards. The phenomenon is of course a sign of mixture, and probably also of a peculiar histological condition in the given iris.

BLONDS AND BRUNETS.

The terms "blond" and "brunet" are general items which have as yet no scientifically fixed meaning. As a result when two persons

and even two scientists speak of blonds and brunets their meaning may differ.

"Pure blonds" may be defined as those persons who have flaxen, blond, golden, yellow, or light brown (near blond) hair, with pure (unmixed) light eyes. More ordinarily, or loosely, all those persons are regarded as "blonds" who have light hair of one or another of the above varieties, with light eyes, whether the latter are pure or would on close examination show traces of brown. And in a still more general way there may be classified as "fair" all those who have hair lighter than medium (including all reds except those of the darkest shades), with light eyes, whether the eyes are pure or would show a mixture on closer scrutiny.

As to "true brunets," that class naturally comprises those with dark to black hair and medium to dark brown eyes. "Apparent brunets" would be all those with dark to black hair regardless of the color of the eyes.

Those who do not enter into any one of the above classes are necessarily the "intermediates."

If we arrange our records on this rational basis, we obtain the following interesting showing:

Old Americans: Blonds and brunets.

(Percentage in round numbers.)

	Pure blonds.	Ordinary blonds. ¹	"Fair." ²	True brunets.	Apparent brunets. ³	Intermediates.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Males (1,009).....	3	5	21	6.5	26	53
Females (914).....	3.5	6.5	24	11	31	46

¹ Includes of course the "pure blonds."

² Includes the pure and ordinary blonds.

³ Includes true brunets.

The above table shows clearly that over one-half of the Old American males and nearly one-half of the females are neither blonds nor brunets, but intermediates. True and even ordinary blonds are scarce, while true brunets are but little more frequent. Using the most general classification we see that approximately but one-fifth of the males and one-fourth of the females may be classed as "fair"; and a little over one-fourth of the males with a little over three-tenths of the females as "dark" or apparent brunets. The nature of these results is a good expression of ancestral light and darker types, with the latter probably slightly in predominance.

The females, even better than in their separate determinations on the eyes and hair, show plainly somewhat more blonds and "fairs" and again more darks, with less intermediates; thus preserving better than the males the ancestral conditions.

REGIONAL DISTRIBUTION.

The regional distribution of the blonds and brunets is shown in the next table:

Old Americans: Blonds and brunets according to region, both sexes.

(Percentage in round numbers.)

	Pure blonds.	Ordinary blonds ¹	"Fair." ²	True brunets.	Apparent brunets. ³	Intermediates.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
New England (106).....	(13)	(18)	(32)	(4)	(22)	(52)
	12	17	30	4	21	49
Eastern States and mixed State ancestry (788).....	(29)	(49)	(171)	(83)	(256)	(361)
	4	6	22	10.5	32	46
South (933).....	(19)	(33)	(211)	(77)	(250)	(442)
	2	4	23	8.5	28	49
Appalachians (126).....	(3)	(6)	(16)	(1)	(19)	(91)
	2.5	5	13	1	15	72

¹ Includes pure blonds.

² Includes pure and ordinary blonds.

³ Includes true brunets.

It is seen that conditions appear with especial clearness in this form. New England stands well above the other groups in the proportion of blonds, and is also below all except the Appalachian group in the proportion of darks; but it has as many intermediates as the South, and even a few per cent more than the East and mixed States.

The South shows fewer true blonds than any of the other groups; but the "fairs" in general are fully as common in the Eastern States as in the South, while brunets, both true and apparent, are even more numerous in the Americans of Eastern and mixed State ancestry than in those of the South.

The Appalachian group is, as has already been shown, quite exceptional, showing but few blonds and even "fairs," but few brunets, and a very large proportion of intermediates.

The relative darkness of the Old Americans of the Eastern States and of mixed State ancestry is not easy to explain, but they have, doubtless, more Dutch and German and also Irish ancestry, which may account for the showing.

COMPARATIVE.

The interest of the results of the observations on pigmentation that form the subject of this paper would be much enhanced could we contrast them with observations on Americans at large and on related peoples. An ideal condition would be if we could also compare them with similar data on the early representatives in America of the families involved, as the present data may perhaps eventually be com-

pared with those on the Americans of the future, but we have no old records of this nature.

The ancestors of the Old Americans, as apparent from the information given the examiner, were very largely, probably more than four-fifths, immigrants from the British Isles. They were English, Welsh, Scotch, Scotch-Irish, with a scattering of Dutch, French (Huguenots), Irish, and German. In the absence of old American records on pigmentation it would in the second line be most desirable, therefore, to have such data from the seventeenth to nineteenth centuries from Great Britain, but these are also wanting. All that is available are data on the English-speaking people from this and the latter part of the last century, and even these we can use only to a limited extent, the observations having been made and recorded in a different manner. As to data from Holland, Germany, or other countries, they could hardly be of help in this connection.

As to data on Americans in general, there are only the very imperfect records of the Civil War, and those equally imperfect obtained during the demobilization after the end of the World War. In neither case were the observations made by scientific or properly trained men. Baxter (Statistics, etc., I, 60) says of those in the Civil War: "The instructions given to surgeons of boards of enrollment were framed with a view to the speediest achievement of the object of the draft, and not to the acquisition of anthropological facts. Thence arose defects in the data, from a scientific point of view, which have often been regretted during the preparation of this work."¹² The "Army Anthropology" volume of the World War¹³ charitably says nothing about the *actual* method of securing the data, though it would have been better to make a straightforward statement. It may suffice to say that the actual examinations and recording, though under the general supervision of good men, had to be made in this case after a brief and insufficient instruction, and often under stress and hurry, by numbers of unselected men from the ranks assigned for the "work" by the officers of the camps; men who had no heart in the work, who had never done anything similar, were unacquainted with the metric system, had inaccurate instruments as well as classification, and were often seen by the writer, who specially visited some of the camps to satisfy himself as to the nature of the examinations, to be grossly careless. Moreover the World War records on the pigmentation of the American born were made wholly worthless

¹² For originals see Gould (B. A.)—The Military and Anthropological Statistics of the War of the Rebellion. 8°, N. Y., 1865; Baxter (J. H.)—Statistics, Medical & Anthropological, of the Provost Marshal-General's Bureau, 4°, 1875, I, 60. See also Statistical Report of Sickness and Mortality in U. S. Army from 1839 to 1855. 4°, Wash., 1856; and Military Statistics of United States of America, 4°, Berlin, 1863.

¹³ Davenport (Charles B.) with A. G. Love—Army Anthropology, 8°, Vol. XV of Statistical Med. Dept., U. S. Army, Wash., 1921.

by an incomprehensible inclusion into these data of those on the "colored." It would be useless to try to contrast such data with those that are the subject of this paper.

As to England, the foremost students of pigmentation in the British Isles so far are Beddoe,¹⁴ Gray and Tocher,¹⁵ Fleure and James,¹⁶ and Parsons.¹⁷ From their data it appears that the pigmentation of the hair and eyes—the skin has not been considered—differs very materially in the different districts and portions of the isles, due to ancestral differences, to an imperfect fusion of the heterogeneous elements of which the population is composed and to local survivals or domination of certain types. The classification of the color of the hair used by these observers agrees fairly well with ours, and we shall be enabled to make some general comparisons; but with the English data on eye-color comparison will be very difficult.

The English records were recently partly summarized by Parsons.¹⁷ Following Beddoe, the English observers classify the hair into fair (corresponding to our "light"), red, brown (our "medium"), dark and black; while the eyes are classed as light, dark, and intermediate. The relation of this classification to ours will appear best in the following form:

Classification of hair and eye color in England and in Old Americans.

	English.	Old Americans.
Hair.....	Fair.....	Light—Blond, golden and yellow, light brown (near blond).
	Brown.....	Light brown (not blond), medium.
	Dark brown.....	Dark.
	Black.....	Black.
	Red.....	Red.
Eyes.....	Light.....	Pure lights—Blues (light, medium, deep), greenish, greyish.
	Intermediate or neutral.....	Mixed.
	Dark.....	Pure browns—Light, medium, dark.

In the case of the hair the two methods agree fairly closely, except as to our "light brown (not blond)" which class is omitted from the English records. In the case of the eyes, however, there is much less agreement. Some of the light browns had probably been re-

¹⁴ Beddoe (John)—*Races of Britain*, 8°. London, 1885.

¹⁵ Gray (John) and Tocher (J. F.)—*The physical characteristics of adults and school children in east Aberdeenshire*. *J. Anthropol. Inst.*, 1900, XXX, 104-124; also *Trans. Buchan Field Club*, 1897.

¹⁶ Fleure (H. J.) and James (T. C.)—*Geographical Distribution of Anthropological Types in Wales*. *J. Anthropol. Inst.*, 1916, XLVI, 35-153.

¹⁷ Parsons (F. G.)—*The Color Index of the Brit. Isles*. *J. Anthropol. Inst.*, 1920, L, 159-162.

corded by the English among the "intermediates"; many light eyes with a brown ring about the pupil or some brown spots, which in our records are all marked as mixed, were doubtless counted by the English among the "lights"; and the slate blues, with some of the darker mixed, they very likely included with the darks.

An additional difficulty for comparing our results arises from the way in which the English records are published. Neither Beddoe nor his followers have given us the general averages for the whole of England and Scotland. They report their observations by counties, cities, and other localities, which is of but little use for our purpose. We have no means of finding out from just what parts of England and Scotland the ancestors of the Old American families were derived, and the best we can do in trying to find what changes, if any, there are now between the people of Great Britain and the Old Americans is to compare the combined records of the latter with similarly combined records on Great Britain, or at least England and Scotland. In order to make some such comparison possible it was necessary to count up Beddoe's detailed data as given by Parsons.¹⁷ The results, contrasted with ours, are as follows:

Color of hair in England and Scotland, and in the Old Americans.

MALES.

Hair.	Old Americans (1,000).	Present England and Scotland (14,537)
Lights proper.....	6.4	16.7
Light brown (not blond).....	16.4	.....
Medium.....	50.4	38.3
Dark.....	23.7	34.8
Black.....	.4	5.8
Red.....	2.7	4.4

These figures are rather striking. Even if we allow for some error in assigning the different colors to their proper classes on each side, enough seems to remain to show that the English present a greater heterogeneity in hair pigmentation. The Old Americans have apparently less real blonds and certainly less darks and blacks as well as reds, with more blends or intermediates. While the total amount of pigmentation is not greatly different in the two units, in the Americans it shows fewer extremes, which is just about what could be expected from their great intermixture. To make the two series still more comparable, the proportion of the "light brown (not blond)" hair among the Americans could probably be safely dis-

tributed one-half to the "fair" and one-half to the "medium" series, in which case we obtain the following relations:

Color of hair in England and Scotland, and in the Old Americans.

MALES.

Hair.	Old Americans.	Present England and Scotland.
	<i>Per cent.</i>	<i>Per cent.</i>
Fair.....	14.6	16.7
Medium.....	58.6	38.3
Dark.....	23.7	34.8
Black.....	.4	5.8
Red.....	2.7	4.4

We still have for the Old Americans less blonds and reds, less darks, and decidedly more intermediates.

So much for the men. With the females the conditions are similar.

Color of hair in England and Scotland, and in the Old Americans.

FEMALES.

Hair.	Old Americans (900).	Present England and Scotland (11,172).
	<i>Per cent.</i>	<i>Per cent.</i>
Fair.....	12.4	13.1
Light brown (not blond).....	10.0	.....
Medium.....	40.3	38.1
Dark.....	29.4	39.3
Black.....	.6	4.8
Red.....	4.7	4.7

On the whole the British and the Old American females seem to agree better as to hair color than the males, but like the males show a considerably larger proportion of dark hair than occurs in the Americans.

The records on eyes show the following conditions in the two groups under consideration:

Color of eyes in Old Americans contrasted with that in Great Britain.

	Male.			Female.		
	Light.	Intermediate or mixed.	Dark (medium and dark brown).	Light.	Intermediate or mixed.	Dark. (medium and dark brown).
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Old Americans.....	31	57	12	24.2	58	18
	88			82.2		
England, Wales, and Scotland.....	66		34	53.3	15.2	31.5
				68.5		

In view of the manner in which the English records were made, there are no means of separating the pure lights from the mixed lights as in our series, but the English "dark" eyes ought to correspond more closely to our medium plus dark browns class. The results show, however, a very much larger proportion of "dark" eyes in Great Britain than among the Old Americans. The more common occurrence among the English of dark to black hair would lead us to expect also a moderately greater frequency in the same series of dark eyes, but the excess of dark eyes is so great as to justify the suspicion that the Beddoe "dark" eye series includes various eyes besides the medium and dark brown, which makes it unfit for comparison with our data. After an earnest effort to utilize the English eye records, we are thus left quite helpless. The probability is that the average present eye pigmentation in Great Britain differs only slightly from that of the Old Americans.

Since Beddoe, the English observers have another and convenient, though somewhat artificial, method of expressing their records on pigmentation, and that is through their so-called "index of nigrescence." This index, as modified by Parsons,¹⁵ is obtained by adding the percentage of the dark brown and black hair to that of the dark, plus one-half of the intermediary or neutral eyes, and dividing the results by two. Unfortunately, as already seen, their classes of eye colors are very different from ours, which precludes any direct comparison.

However imperfect our efforts at comparison with the English may have been, they leave two impressions of value. The first is that both the Old Americans and the English, if classed by the mean value of their pigmentation, fall not into the "fair" but into the intermediary or medium-pigmented group, which tapers on one side to the fair and on the other to the brunet. The second fact is that the English show in their midst less intermixture with consequent blends than do the Old Americans.

The lack of marked difference in pigmentation between the Old Americans and the English does not denote, however, that no changes in this respect have taken place in the Americans since the arrival from Europe of their ancestors. It is quite possible that a gradual progressive darkening has proceeded in both groups. There are observers in both countries who incline to that opinion. Pigmentation is essentially an environmental and changeable condition, however slow the changes may be. Neither England, nor certainly the United States, are in the sphere of the nordic countries, where blondness was produced and where it is being sustained. And the composition, climate, habits and food of the people in the United States

¹⁵ *J. Anthropol. Inst.*, 1920, 162.

and Great Britain are so similar that the two people might well be assumed, on general considerations, to show a parallel line of changes in a physiological characteristic such as pigmentation.

The whole subject in both countries needs a thorough scientific restudy on a large scale. It would be a fallacy to believe that observations, however superficial they might be, if only made on a large enough number of subjects, would ever show true conditions; such data can at best only approximate, but may also more or less mask, if not pervert, the real facts.

GRAY HAIR.

In 250 of the examined men and 200 women, special attention was given to the subject of the graying of hair.

The ordinary notions as to grayness are very empirical and superficial, yet there is much of interest to be learned in this connection. The condition, however, is not easy to study. Few elderly people remember correctly when they began to notice gray hairs or how the process progressed; and even for the scientific observer it is not easy to estimate correctly the many grades of the change.

The best way to proceed in the study of graying was soon seen to be the statistical, and the only effective way of recording was found to be by estimates in percentages of the quantity of the gray hair in relation to all the hair on the head. Accordingly the incidence of gray hair was recorded as: None; very few to few; some to one-third; approximately one-half (two-fifths to four-sevenths); two-thirds to nearly all; and all. The observations gave the following results:

Old Americans: Grayness.

	None.	Very few to few.	Some to about one-third.	Approximately one-half.	Two-thirds to near all.	All gray (more or less completely).
	(107)	(47)	(33)	(11)	(41)	(11)
Males (250).....	42.8 per cent.	18.8 per cent.	13.2 per cent.	4.4 per cent.	16.4 per cent.	4.4 per cent.
Mean age (42.6 years).....	22-48 years..	24-55 years..	25-37 years..	37-53 years..	39-65 years..	48-65 years.
	(104)	(30)	(29)	(9)	(21)	(7)
Females (200).....	52 per cent.	15 per cent.	14.5 per cent.	4.5 per cent.	10.5 per cent.	3.5 per cent.
Mean age (41.8 years).....	24-48 years..	24-55 years..	30-53 years..	37-59 years..	39-60 years..	51-60 years.

These data only show that grayness long before old age in both sexes is frequent; that there evidently is throughout adult life a slightly less tendency to it among females than among males; that for some perhaps not strictly physiological reason there is an undue frequency of the two-thirds to all grays in both sexes, and that both

in appearance and progress of graying there is great individual variation.

Some further light on the condition may be had by arranging the data by age:

Old Americans: Grayness of hair in relation to age.

MALES.

Age and number of subjects.	None.	Very few to few.	Some to one-third.	About one-half (two-fifths to four-sevenths).	Two-thirds to near all.	All.
24-30 (100).....	74	18	6	1	1	.....
31-40 (63).....	44.4	27	19.0	3.2	6.4	.....
41-50 (44).....	9.1	20.4	27.3	11.4	27.3	4.5
51-60 (35).....	2.9	8.6	8.5	8.6	51.4	20.0
61-65 (8).....					75.0	25.0
Total (250).....	42.8	18.8	13.2	4.4	16.4	4.4

FEMALES.

24-30 (80).....	85	11.2	3.8			.....
31-40 (63).....	47.6	25.4	19.0	4.8	3.2	.....
41-50 (29).....	13.8	17.2	37.9	10.3	13.8	6.9
51-60 (28).....	7.1		10.7	10.7	53.9	17.6
Total (200).....	52	15.0	14.5	4.5	10.5	3.5

Thirty per cent approximately of the Old American men and 11 per cent of the women have a few to over one-third of gray hair before they pass their thirtieth year. Between 31 and 40 less than half of the males and a little less than three-fifths of the females are without gray hair, and the proportion of such persons is reduced to a little over 10 per cent during the next decennium. Over 35 per cent of the males between 41 and 50 and 16 per cent of the females between these ages show already grayness that involves from two-thirds to all the hair; and for those between 51 and 60 this proportion rises to very nearly three-fourths of the males and seven-tenths of the females.

The females show throughout slightly less tendency to graying than the males. Undue predominance of the two-thirds to nearly all gray is shown again.

Some day, when we shall have equally detailed data on graying in other peoples, the above figures ought to make interesting comparison and lead to some definite deductions of anthropological nature.

TEMPORARY GRAYNESS.

The phenomenon of sudden or very rapid graying, generally under the stress of great fear, anxiety, or other deeply disturbing nervous effect, is well known, though more so popularly than to science; but the sequences of such a change are only seldom mentioned. A striking case came to the writer's attention in the course of the studies here reported. It concerns General Greely, the Arctic explorer. General Greely was born in 1844. His hair when he reached the adult life was "chatain" or rather dark brown and it remained so, with probably the appearance of a few gray hairs, until 1884, or towards the end of his exceedingly difficult trip of Arctic exploration. Then within the period of some months, under the anxieties and privations of his position, his hair turned completely white. But upon a return to civilization the whiteness began gradually to disappear, until the hair returned to nearly its former condition, after which graying progressed naturally. The following brief personal statement will make a clear record of the case:

COSMOS CLUB,

Washington, D. C., March 8, 1922.

DEAR DR. HRDLÍČKA: Referring to our conversation a few days since, I confirm my statement that when rescued at Cape Sabine in 1884 my hair was entirely white, due probably to the *continuous* condition of semistarvation from which I suffered for over nine months. Within a year my hair darkened very considerably, though it never returned *entirely* to its original chatain coloring.

Yours,

A. W. GREELY, *Major General.*

DR. A. HRDLÍČKA,
Washington, D. C.

LOSS OF HAIR.

In modern civilized men the hair of the head does not merely tend to grow gray earlier than in more primitive people, but generally also it is more or less shed as ageing advances, showing a reduced vitality. It would be wrong to attribute either of these phenomena to any particular habits of civilized man or to pathological conditions, though both of these may play a part at times; the real causes are already hereditary and thereby of a phylogenetic nature. The hair tends towards an earlier senility and loss, because it has become of less organic use to man living under modern conditions than it has been in the past, and nature does not tolerate for long what has become useless or weakened. Both early graying and physiological loss of hair are a part of the trend of present evolution in civilized humanity.

Unlike grayness, however, normal loss of hair is largely linked with the male sex. Women lose hair too, and that probably at an increasing rate, but not in the proportion in which the process goes on in the males.

A special inquiry into this subject among 250 male and 200 female Old Americans, taken without any selection, showed the interesting results given below. As all the females were examined with their hair undone and freely hanging down to permit the unimpeded taking of head measurements there can be no question of the observer having been misled.

Old Americans: Loss of hair.

Loss.	Males (250).			Females (200).		
	Cases.	Ages.		Cases.	Ages.	
		Average.	Ex- tremes.		Average.	Ex- tremes.
	<i>Per cent.</i>			<i>Per cent.</i>		
No plainly appreciable.....	45.2		24-60	85		23-60
Slight.....	13.6	37	24-60	11	44	29-55
Some to one-third.....	22.4	39	24-57	3		
Approximately one-half.....	7.2	46	29-65	1		
Two-thirds to near all.....	11.6	49	35-64			

Old Americans: Loss of hair in relation to age.

MALES (250).

Age and number of subjects.	None perceptible.	Slight.	Some to one-third.	Approximately one-half (two-fifths to four-sevenths.)	Two-thirds to near all.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
21-30 (100).....	68	11	17	3	1
31-40 (63).....	46	17.5	22.2	4.8	9.5
41-50 (44).....	29.6	18.2	34.1	6.8	11.3
51-60 (35).....	8.6	8.6	25.7	20	37.1
61-65 (8).....		12.5	12.5	25	50

FEMALES (200).

21-30 (80).....	98.8		1.2		
31-40 (63).....	95.5	1.5	1.5	1.5	
41-50 (29).....	85	5	10		
51-60 (28).....	84.3	5	7.1	3.6	

The above figures show that loss of hair in the Old Americans presents wide individual and even wider sexual variation. There were seen men and women of sixty in whom there was as yet no appreciable loss; but on the other hand plain thinning was seen not merely in some of the youngest male adults of the series but even in some subadults down to 18 years of age. The progress of the con-

dition, once it has set in, is generally continuous though not always regular.

The great difference in the frequency and average grade of the loss of hair between the males and females is difficult to explain. Possibly the weight of the female hair acts as a tonic. The differences between the head covering in the males and females may also have an effect. But in all probability a more or less male-linked predisposition to the condition is already inherited.

In this case, again, we have no similar data on other peoples that could be used for comparison; but as interest in these secondary manifestations will grow, such data will doubtless be forthcoming.

CONCLUSIONS.

The above data on the eyes and hair permit the formulation of the following conclusions regarding pigmentation in the Old Americans.

SKIN.

1. Two-thirds of the old stock males and three-fourths of the females show skin that may be classed as medium.

2. In only 5 per thousand in males, but in 52 per thousand in the females, is the skin plainly lighter than the medium. All of these cases are associated with pure light eyes and light or red hair.

3. In a little over one-fourth of the males and in one-sixth of the females the skin is perceptibly darker than medium. Such skin is generally associated with brown eyes and medium to dark hair.

HAIR.

1. Only 1 among 16 males and 1 among 14.5 females has real blond hair.

2. One-half of the males and over four-tenths of the females show medium dark (or "medium brown") hair.

3. In one-fourth of the males and three-tenths of the females the hair is dark ("dark brown") to near black.

4. In approximately 1 per cent in the males and but a little more in the females the hair is fully black.

5. In 2.6 per hundred of males and 4.9 per hundred of females the hair is red or near red.

6. The females show a slight to moderate excess of true blonds (especially golden and yellow), but also of darks, blacks, and reds, over the males.

7. There are some areas in which hair pigmentation among the Old Americans, due to isolation and more thorough mixtures, differs from that of the group as a whole.

8. Differences between the "Yankees" and the Southerners in this respect are only moderate, the former showing somewhat more lights, less darks, few if any true blacks and less reds. But the Southerners show almost identical conditions in regard to hair pigmentation as those of the central states and those of mixed-state ancestry.

EYES.

1. Approximately one-third of the eyes of the males and one-fourth of the eyes of the females of the Old Americans are pure lights.

2. One-sixth of the males and one-fifth of the females show eyes the iris of which is pure brown (light, medium, or dark).

3. Over one-half of the males as well as females have eyes that show plain traces of brown with light.

4. There are on the whole more light and less dark eyes than there is of light and dark hair.

5. Regional differences are less marked than with the hair, except in isolated localities.

6. There is a considerable but not a complete correlation between the pigmentation of the eyes and that of the hair. Light eyes may in some instances be associated with dark (though not black) hair; but medium to dark eyes are as a rule accompanied by medium, dark, or black hair.

BLONDS OR BRUNETS.

1. The classification of the Old Americans on the basis of both the color of the eyes and hair brings out with special clearness a number of the conditions relating to pigmentation.

2. Over one-half of the males and nearly one-half of the females are "intermediates."

3. Blonds are scarce, as are also true brunets, but the latter are plainly more frequent, especially in the females.

4. The females show slightly more blondes, more brunettes and less intermediates than the males.

GRAY HAIR.

1. In general, grayness manifests itself early in the Old Americans.

2. In the males, grayness proceeds apparently faster than in the females.

3. There is wide individual variation.

LOSS OF HAIR.

1. There are great sexual differences in this respect. The males lose hair sooner, more rapidly and much more extensively than the females.

2. In males loss begins at times even before the adult stage is reached; and after 55 there are very few men in whom some degree of loss at least has not taken place.

3. Wide individual differences exist also in this respect.

COMPARISONS.

1. Suitable data for comparison are scarce. From what is available it appears that the pigmentation of both hair and eyes in the Old Americans is much like that of the present population of Great Britain, though the latter appears to show some excess of both dark eyes and dark hair.

2. As to changes with time, it seems probable that in both Great Britain and the United States there is taking place a slow progress towards a darker pigmentation of both eyes and hair, though the fact needs definite confirmation.

ANCESTOR WORSHIP OF THE HOPI INDIANS.

By J. WALTER FEWKES,
Chief, Bureau of American Ethnology.

[With 7 plates.]

There coexists among the Hopi, with sun and fire worship, already described,¹ another type of religious expression to which with much hesitation is given the name Ancestor Worship—the cult of the *Katcinas*, spirits of the deceased or “other members of the clan.” An attempt is made in the following pages to outline the objective or salient points of this worship.

The mystery of life has made such a profound impression on the mind of man in all stages of education that attempts to explain it are coeval with the origin of human consciousness. But despite all philosophic inquiry and researches of biologists the question, “What is life?” still remains unanswered. The great variety of genera and species catalogued by naturalists and the brilliant contributions of the embryologist and the experimental botanist and zoologist have led many thinkers to believe that this riddle of the universe may ultimately be solved on a material basis while others remain still skeptical that consciousness can ever be explained by this method of investigation.

The untutored mind, ignorant of the great advances made in the interpretations of physical and vital phenomena, regards life as a magic power incapable of explanation. The scientific mind is confident that the nature, origin, future, and interrelations of life, being the highest subjects of scientific investigation, will later be comprehensible.

It is recognized by men of all races that man has a life independent of the body, and this belief in the future life is well-nigh universal among the North American Indians. There is evidence that the same idea was widespread among aborigines on this continent in prehistoric times. This vital element, known as the spirit or “breath-body,” is recognized as distinct from the physical body that dies and decays. Not only has man an individuality distinct from his body, but also

¹ See Smithsonian Reports for 1918 and 1920.

everything else organic and inorganic has life, which may be influenced by magical processes, rites, songs, and prayers. The Hopi believe that a few days after burial this spirit leaves the grave and follows the sun to his realm in the underworld. It is customary to place bowls containing food on the grave, and it is thought that the spirit of the food nourishes that of the dead, but coyotes or other wild animals consume the material food left in these mortuary bowls. Prayers are said to the spirit.

There exists also a belief that is strictly aboriginal—having originated independently of white influence, although possibly somewhat modified by it—that the spirits of the dead return to earth either to vex or bless mankind. The place of abode of the various tribes who believe in a future life is supposed to be the underworld. Of this abode little is said by the Indians, but there are descriptions of it in Hopi stories, showing that in their minds life in it is like that on the surface of the earth.

This world, inhabited by spirits of the dead, or the underworld, is spoken of in a vague way as being the home of the unborn. Out of it in the beginning came the races of man. It might be called the womb of the earth, while the place of emergence is known to the Hopi as the *sipapu*. The life of the spirits of the dead in this underworld resembles that on its surface. Here they preserve their clan organization, have their altars and sacred rites, and plant and harvest.

The relation between the living and the dead is apparently not severed by death, but the "breath-bodies" of those that have passed on revisit the pueblo and are represented by masked personations called *Katcinas* (pl. 1), which are past members of living clans. They are identified as ancestors, but perhaps it would be better to call them "other clan members." These personations of the dead, or *Katcinas*, return to the earth and take part in the pageants, also called *Katcinas*, that indicate many existing beliefs of the Hopi as to their nature.

Various definitions have been given of the word *katcina*. It was derived by one writer from the Spanish word "*cochino*," pig; by another from *katci*, life, *na*, father of, a much more probable interpretation. The word is not confined to the Hopi, but is widespread in the Rio Grande pueblos, from which it possibly originally came. The Zuñi equivalent appears to be *koko*, and it is instructive to note that *Katcinas* or *Kokos* are believed to return to the "Dance Hall of the Dead," Kothualowan, said by both Hopi and Zuñi to be situated at Winema, in the Little Colorado Valley, about midway between the two peoples.

It is the author's belief that the idea of personating the ancients by masques existed in the Rio Grande pueblos and that it was transmitted to the Hopi mesas via the Little Colorado Valley.

The symbolic home of the Hopi Katchinas is ceremonially associated with the San Francisco Mountains, Ariz., far to the southwest of the Hopi but in sight of their pueblos. On account of this association personifications of the Katchinas sometimes wear twigs of cedar in their belts, wristlets, or armlets. In the mortuary ceremonies of the Hopi the defunct is addressed as a Katchina: "You have become a Katchina; grant our request," is the burden of a prayer to the dead.

The "breath-bodies," or spirits of the dead, are supposed to follow the sun as it sinks in the western sky. The place of sunset at the winter solstice is behind a notch on the horizon silhouetted against the sky and known as the Sunhouse, indicated by a depression between the San Francisco Mountain and Eldon Mesa. The festival that celebrates the departure of the Katchinas from Walpi is known as *Niman* (go home) Katchina. The dancers perform the last dance of their departure about sunset, after which they follow the western trail "down the mesa." In the foothills near this trail is the shrine where the offerings to the dead are deposited, often called the Badger shrine, because the Badger clan is said to have introduced the important Katchinas, whose altars are erected in February on the dramatization of their arrival and in July when they formally leave the pueblo.

While the author was living at Walpi in 1900 he was informed one day that the Hopi were in great distress because the covering of this shrine had been removed, and the mystic Badger had emerged from the underworld and was burrowing in the graves of the dead. So intense was the superstitious feeling of the evils this event portended that no one would even venture into the neighborhood of the shrine. Even the men who reported the event could not be induced to go to this place and determine the damage. After a few days, however, the fear subsided, as some persons killed a real Badger, who had been detected burrowing into the earth at the foot of the mesa near the cemetery. This dread of the offended mystic Badger was allayed by prayers and incantations. The opening through which he emerged from his subterranean home is the shrine where prayer sticks are placed by Katchina personators.

A Katchina dance is a family festival in which the ancients, personated by masked men who are supposed to become these supernatural beings when they put on the masks, participate. The identification of the clan to which they belong is indicated by the symbolism depicted on the mask, much of which is probably secondary in origin and explained by myths known to the initiated. When an explanation is sought for the meaning of this symbolism it should be obtained from members of the appropriate clan, as those not belong-

ing to the clan do not pretend to know the meaning of the symbols on masks of other clans.

The Katsina masks are commonly kept hanging on the wall of back rooms in the pueblo, and as they are needed year by year are repainted and redecorated for use. Most of the helmet masks (figs. 1, 2) that have been examined are not very old, many being made of old bootlegs or leather from old Spanish saddles, or even cloth or



FIG. 1.—Katsina helmet-mask.

felt hats. There are, however, many ancient masks kept as heirlooms and never brought out in public dances which are still preserved, even when the clans that once used them have become extinct.

The masked or Katsina dances ordinarily occur in the summer months and vary somewhat each year. The arrival and departure of the Katsinas are fixed festivals and never vary, but at some time in the course of winter or early spring the Hopi chiefs hold an informal council to determine what particular abbreviated Katsinas they will

personate the ensuing summer. Although there is no standardized program year after year, there is a similarity in successive years, and there are certain dances that are very popular; others that are performed in payment to a neighboring village that has visited them a former season. The variety of masked dances on the East Mesa is great, for there are three pueblos on this plateau and two different languages spoken: Tanoan in Hano, and Hopi in Walpi. The inhabitants of Sitcomovi also speak the Hopi language, and the characteristic masked ceremonials the three pueblos perform



FIG. 2.—Side view of Duck Kachina helmet.

are somewhat different. The names of the masked dancers at Sitcomovi are derived from the Zuñi language; the ceremonial dancers, altars, and other ceremonial paraphernalia of Hano have Tanoan names.

It is natural that the existence of these three pueblos of divergent linguistic and clan origins should have led to a greater variety of nomenclature, and Kachina personations that occur on the East Mesa are absent on the Middle Mesa and Oraibi.

Walpi is the dominating pueblo of the East Mesa. Naturally it has been most studied and has a typical Hopi ritual, but it is more or less affected by alien elements. As compared with other pueblos

there are variations in rites, or cult objects, and often the priests offer fundamentally different explanations of rites. These variations are in part due to acculturations; but also in part to syncopations, which have been so great as to obscure original meanings.

The place in the ceremonial system occupied by the masked dances may be indicated by an examination of a few features of the ritual. Data regarding the way the Hopi regard the Katcinas and their association with the ancients comes out very clearly in an episode in the new fire rite at Walpi. After the new fire is kindled in the chief kiva two of the societies file down the mesa by the ladder trail south of the pueblo, and make a circuit around the old ruin once the home of the Walpians, situated on the terrace near the southwest end of the mesa. "What are we doing now?" I asked one of the priests. "Down there they dwell; down below the ruin the Katcinas live in the underworld and we are now saying our prayers to the ancients who formerly lived in the houses of the Ash Hill Terrace, our ancient pueblo."

There seems to be in the minds of the Hopi priests a recognition that the life of the Katcinas or ghostly inhabitants of the realm of the dead is somewhat like that on earth and that their sociological condition reflects the same. The inhabitants of the lower world are arranged in clans the same as on earth. Legends indicate that the deceased Hopi plant and harvest, that the dead have ceremonies and altars, or, in other words, that the customs of those who occupy the abode of the dead resemble those living on earth.

There are said to be four underworlds, one below another, and from these prenatal worlds the races of man in the beginning climbed from one to another, at last emerging through the *sipapu* or a mythic opening recognized by all the Pueblo Indians as communicating between the abode of the living and that of the dead. This *sipapu* or place of emergence is commonly said to be geographically situated in the north, where it is associated with a body of water or lake. The geographical place of emergence, at least of some Hopi clans, is reputed to be the Grand Canyon of the Colorado, known as "Far Below River." This emergence legend may be a poetic way of expressing their evolution from a cultural condition in which they lived in earth lodges or holes or caves in the earth. Legends describing their origin from the underworld furnish scanty details of a previous cultural condition. The subterranean room, or kiva, is supposed to symbolically represent one of these underworlds; but there is an opening in the floor of the kiva supposed to communicate into another room below it, while the hatch opening of the kiva is the passageway from the underworld to that in which man now lives.

In the organization of the Hopi there is a large social unit of Tewa extraction called the Asa or Tansy Mustard "clan," from the fact that in its migrations the mothers stilled the cries of the babies hanging on their backs by shaking a tansy mustard flower before their eyes. This clan came to Hopi from Zuñi, where members still live and are called Aiwahokwe. The majority of the Asa live in Sitcomovi, the "Zuñi pueblo" among the Hopi. The masks (pl. 2) of this clan bear no symbol indicative of the tansy mustard or any other flower, which would lead us to believe that clan names change while symbols remain constant, or are more ancient.

The festal year at Walpi contains many elaborate ceremonies which, roughly speaking, fall into two groups, the summer and winter festivals; the former, the masked, are Katcinas, which are radically unlike the unmasked dances of the latter. Some of these occur at regular intervals; others are more sporadic, but no moon waxes and wanes over Walpi without witnessing a religious pageant of some kind, which, for obvious reasons, will be more striking in the summer months but more elaborate in winter, since at that time the agriculturist has no work in the fields and the cold has driven the whole population into the pueblo.

The primitive astronomers or sun priests have given names to the different points on the horizon behind which the sun rises or sets corresponding to all the great festivals. When by means of this solar clock the time of the ritual year is determined they inform the speaker chief or town crier, who makes a public announcement. At sunrise he stands on the highest roof of Walpi and shouts the news of whatever events will occur, informing those who are to take part to make their preparations.

The great ceremonials occur annually on about the same date and in a sequence. In order to determine the date on which a ceremony occurs the aboriginal Hopi relies on the position of the sun at sunrise or sunset. The eastern and western horizons are used as great solar clocks. When, for instance, the sun sets behind the San Francisco Mountain, or the "mountains of the high snows", our luminary has reached the farthest point south, or the winter solstice. The point on the horizon behind which he sinks is called the Sun House of the West. Possibly the belief that the dead follow the sun to the west and the position of the house of the sun behind the mountains of the high snows has led to the legend that the Katcinas live in these mountains; as symbolic of that belief the Katcinas wear cedar boughs in their armlets, belts, and on their masks.

The following ceremonial calendar, beginning with the New Fire in November, which opens the Hopi year,² contains a list of the important Katsina celebrations:

1. New Fire ----- November.
2. Winter Solstice. Return of the Soyal Katsina ----- December.
3. Abbreviated Snake or Flute ceremony on alternate years. Return of the Zuñi Katsinas ----- January.
4. Return of Badger and other clan ancestors ----- February.
5. Abbreviated Katsinas ----- March-July.
6. Departure of Badger and other clan ancestors ----- July.
7. Snake Dance or Flute on alternate years ----- August.
8. Basket Dances ----- September-October.
9. Tablet Dance from Awatobi³ (now abandoned, 1922) ----- October.

The composite nature and intricate social formation of any one of the Hopi pueblos and the probability that each of the component clans formerly had its own ancestor worship has rendered the Katsina cult at the East Mesa very complex and the significance of the dances difficult to explain. Where the clan has become very much reduced in size, naturally its Katsina exhibition is correspondingly limited and in some instances it is so small that it has joined in the celebration of a more powerful family of nearest kin. Thus in the *Powamu* or that called the Return of the Katsinas, which is mainly controlled by the *Honani* (Badger) clan, we find masked personages of several other clans. The return of the *Soyal* Katsina is abbreviated and represented as a secondary or supplementary part of the winter solstice rite. The nearest approach to the unabbreviated original type of Return Katsinas, as shown in *Powamu* of the *Honani* clan, occurs in January and is celebrated by the descendants of the Zuñi clans where the Katsinas with Zuñi affiliations and names are represented at Sitcomovi. The original simplicity of the clan religion has been greatly modified by union and consolidation in the pueblos of the East Mesa.

It would appear that the Katsinas have a clan organization but they do not all belong to the same clan, which naturally suggests that the social condition of life in the underworld is similar to that on this earth and organized in a like manner. Those who belong to the Badger clan on earth are still members of the same clan after leaving the mortal body. In other words each earthly clan has its corresponding clan in the underworld and in representations of those clans by masked personages the relatives are indicated by the same names and symbols, a suggestion that may explain the existence of very many kinds of Katsinas as well as the character of their per-

² This is not intended as a complete list of ceremonies at Walpi, which is published elsewhere.

³ A ruined Hopi pueblo destroyed in 1700 A. D. by the other Hopi. Vide: 17th Ann. Rept. Bureau American Ethnology.



Photograph by J. W. Fewkes.

RAIN KATCINAS AT WALPI.



Photograph by James Mooney.

KATCINAS OF ASA CLAN, CALLED THE NATAKAS, IN HOPI BEAN PLANTING CEREMONY.



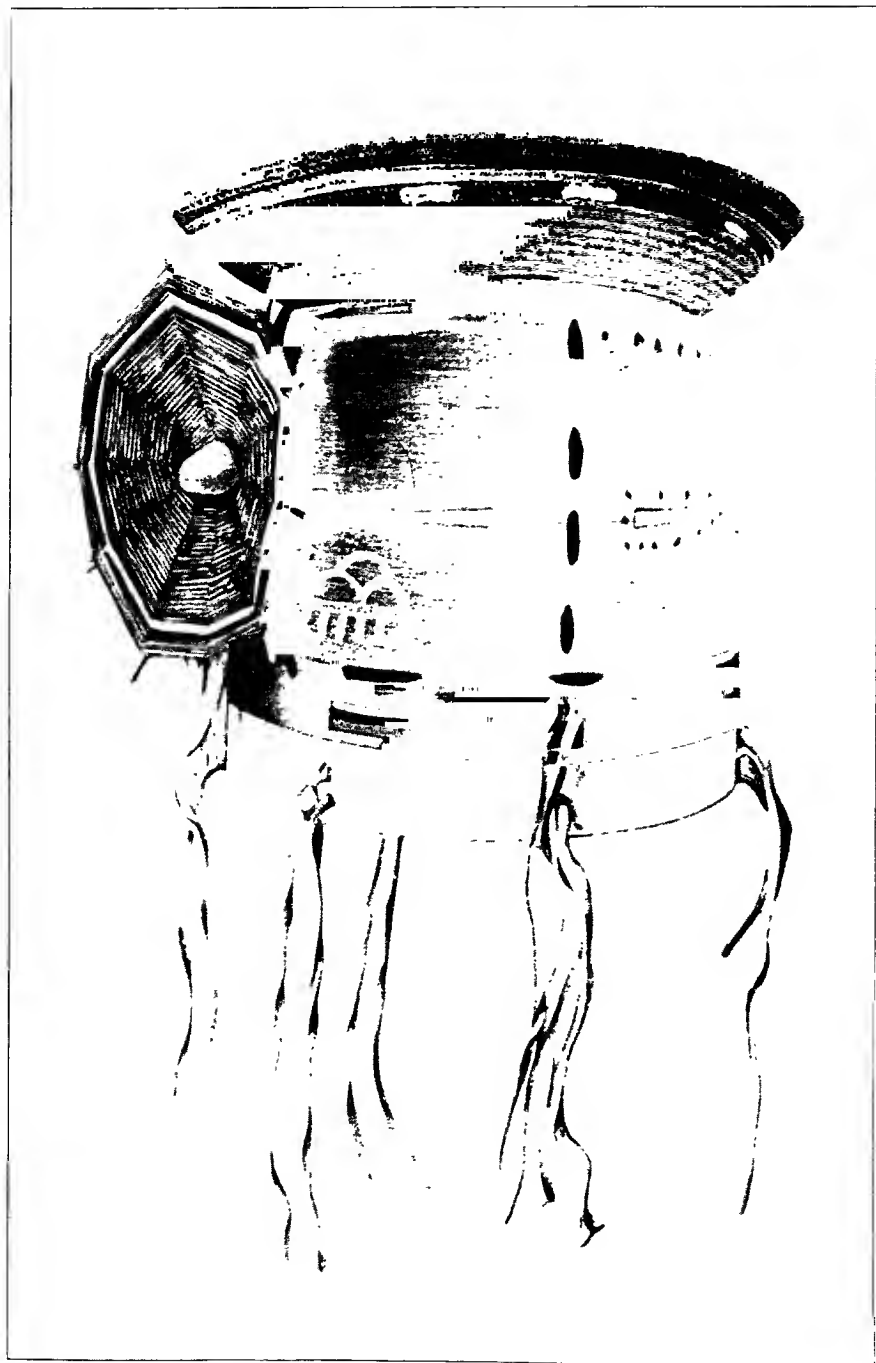
INDIAN DRAWING REPRESENTING A WAR KATCINA. THE OBJECT IN THE
RIGHT HAND IS A WHIZZER OR "BULL ROARER."



1. PERSONATIONS OF ANGYA KATCINAS.



2. KATCINA MAIDS PLAYING ON "HOPI FIDDLE."



KATCINA HELMET WITH RAIN CLOUD SYMBOL OR CHEEK, SQUASH BLOSSOM
SYMBOL ON ONE SIDE.



1. PLACE WHERE KATCINAS DISROBE. ON RIGHT, KILTS, FOX SKINS, AND SASHES HANGING ON THE CLIFF; LEFT, ROW OF HELMETS; CENTER, GROUP OF MEN EATING LUNCH.



2. THREE KATCINAS; THE MIDDLE FIGURE, REPRESENTING THE LITTLE WAR GOD, CARRIES LIGHTNING FRAMEWORK IN HIS LEFT HAND.



Photograph by James Mooney.

PERSONATIONS OF NATACKA KATCINAS.

sonations (pl. 3). Consequently the Hopi pantheon is well stocked with clan ancients resembling each other in general particulars but differing considerably in their totemic or symbolic characters. The union of several clans makes it very difficult to properly reconstruct the original typical form in many cases.

Every great Hopi ceremony has an elaborate and an abbreviated, a greater and a lesser performance, commonly six months apart. The elaborate exhibition as a rule extends over nine days. Several of these days are occupied with secret observances in a kiva or ceremonial room, but the public are welcomed to all pageants or open dramatizations that customarily close the series of daily rites that make up the celebration.

The scheme of the dramatic dances in which Katcinas appear is simple. These personations are believed to live in a far distant land during the winter months but to visit the villages during the summer. Their arrival and departure are two very important ceremonial events and are appropriately celebrated; their advent occurs annually in February and their departure in July, six months apart. The dramatic representations of their coming and going are the great festivals. *Powamu* and *Niman*, celebrated in secret rites as well as open masques. At their advent they are led into the pueblo by a personation of the sun, the father of all life, as described in the account of sun worship among the Hopi. They enter the town from the east and depart toward the west, and between their advent and their departure they wander about in the field or in the pueblo, from time to time performing open dances in the courts of the villages. The celebration when they arrive or depart extends over several days and nights but in the abbreviated or intermediary personations their dances are limited to a single day.

As the most showy part of these dances are the masked personators (pl. 4, fig. 1) an explanation of the character of the symbolism, mainly expressed on the mask, is important. In a typical Katcina dance there are three or four impersonators that appear. The largest number are called Katcina *takamu* or Katcina men. They wear on their heads the helmet masks, the symbolism of which differs according to the Katcina personated (pl. 5). Facing them are the Katcina *manas* or Katcina maids, often called "sisters," generally six in number. These are men dressed as maidens wearing the white wedding blankets made of cotton similar to those that every Hopi bride receives from the clan of her husband as part of her wedding trousseau. These "sisters" face the men as they dance; they carry in their hands sheep scapulas which they draw over a notched stick, making a rasping noise accentuated by a hollow gourd placed on the ground, upon which the stick rests. This is called the "Hopi fiddle" (pl. 4, fig. 2). The rhythm of the dance is also aided by the rattles

the men carry in their hands and by empty turtle shells with attached deer hoofs tied under the knees.

These dances are accompanied by a group of masked men, generally five in number, known as the Clowns, Mud Heads, or Delight Makers. There are three kinds of clowns: the first, those who wear a close fitting cap with long leather horns tipped with bunches of corn husks. These horns, like their bodies, are girt with black and white bands like convicts' garments; the second have their heads encased in close fitting hoods to which are tied little bags like wens, some of which resemble small sausages; the third group is unmasked and have their faces painted with yellow and red pigments. They wear necklaces and ear ornaments made of the tails of rabbits stained red. The third group might easily be called gluttons for they practice inordinate eating, sometimes consuming disgusting food. None of these personators wear clothing of any kind save a gee-string. Their function is to amuse the spectators while the public dances are progressing, introducing impersonations and ludicrous episodes, many of which would better not be described. These clowns, especially the last mentioned, represent the very ancient ancestral people (fig. 3).

The wants of the people are made known to the Katsina personators by prayers of old priests who from time to time pass about the line of dancers sprinkling prayer meal in pinches on their shoulders, accompanied with prayers. These Katsina personations are supposed by the worshippers to have supernatural powers to bring the rain, and make the crops grow, and the purpose of the prayers is in that direction. The old priests vicariously represent the worshippers, and as they pass from one dancer to another they give them prayer sticks that have been consecrated by songs, prayers, and in other ways sanctified in the sacred rooms before an elaborate altar.

The one-day public Katsina dances among the Hopi take place in the courts and are performed at intervals from sunrise to sunset, culminating in number of performers and size of the audiences late in the afternoon. The line of dancers is generally led to the dance places by a priest who indicates the trail by throwing a line of sacred meal in front of the leader. These men are priests who pray to the Katsinas either by asperging medicine water on them or sprinkling them with prayer meal.

The songs of the Katsinas are melodious and rhythmical, the words often incomprehensible, sometimes taken from some other pueblo language. They are often bartered among different Hopi pueblos and it is no unusual thing for a man from one pueblo to teach a foreign Katsina song to men of another pueblo, for a remuneration. To emphasize the value they place on some of these songs attention may be called to the fact that a new Katsina song is sometimes sold for a

very high price. Before a dance the performers often rehearse in the kivas where novices are taught the standard Katsina songs.

Children are sometimes allowed to perform a Katsina dance of their own, similar to that of their elders, and it is an interesting experience to witness these performances, the mothers taking consider-

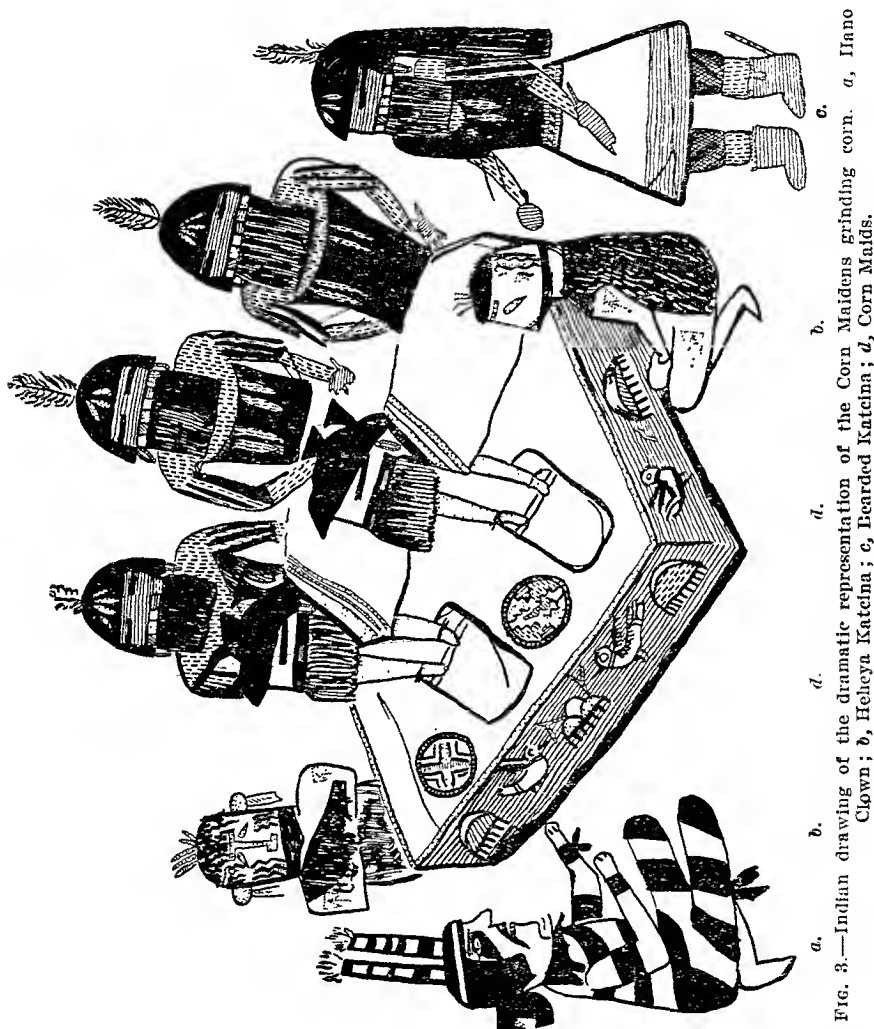


FIG. 3.—Indian drawing of the dramatic representation of the Corn Maidens grinding corn. *a*, Hano Clown; *b*, Heheya Katsina; *c*, Bearded Katsina; *d*, Corn Maids.

able pride in dressing the little boys for this dance. One or more of the performers at this time carries a bag of piñon nuts which he throws at intervals among the assembled spectators.

Many Katsinas have been lately introduced into Hopiland, and have no relation whatever to ancestors of Hopi clans (pl. 6). They are not personations of ancients, elders or other members of Hopi

clans and not so regarded. A Hopi on a visit to some pueblo of another stock, as Zuñi or Jemez, witnesses a dance which pleases him and he acquires the appropriate songs; forthwith on his return home he teaches them to his fellows, and they introduce a dance, which is afterwards known as the Zuñi, Jemez, Cohonino, or other Katcinas, according to its derivation. These masques no doubt had in their parent pueblos much the same relation to local clans as true Hopi Katcinas to Hopi clans, a connection lost in their transportation to a new environment. There are other Katcinas, which are simply spectacular exhibits devoid of kinship to Hopi clans, among which may be mentioned a masked dance elsewhere described⁴ in which many different kinds of birds—eagle, hawk, owl, roadrunner, humming bird *et alii* (figs. 4 to 8)—are personated, as elsewhere described.

There are two distinct languages spoken on the East Mesa of the Hopi; one, the Hopi tongue, the other the Tewa. The latter language is quite incomprehensible to the inhabitants of Walpi, although the Tewa understand the Hopi, a condition which is naively explained by a folk tale which recounts how when the Tewa, on invitation of the Hopi, came into the country the Hopi chief touched their tongues with the soil of his country, but as there was no Tewa soil available with which to touch the tongues of the Hopi, they cannot speak the language. The survival of the Tewa tongue in a village a gunshot from Walpi where a different language is spoken is one of the interesting linguistic features of the inhabitants of the East Mesa, and is largely explained by the sociological fact that both Tewa and Hopi have the mother or clan right, the husband going to the wife's mother's house to live. The children learn their language from their mother, and as the mother does not change her domicile when she marries a Hopi man she has no opportunity to learn her husband's language. The Hopi outnumber the Tewa and the Hopi men who seek wives among the Tewa readily teach the children Hopi, as do also the Hopi wives the few Tewa men who marry among them.

The typical clown who appears in the Katcina dances of the Tewa is known by the alternate stripes of white and black painted on the naked body and limbs. Each of these clowns wears on the head a close-fitting cap made of leather or basketry with two vertical horns, to the extremities of which are tied corn husks. These horns like the legs and arms are girt with alternating rings painted black and white.

In addition to this type of clown the Hopi have another called the Mud Heads who were introduced from the Little Colorado Valley,

⁴ For an account of this masque vide: Hopi Katcinas drawn by Native Artists, 21st Ann. Rept., Bureau American Ethnology.

and are identical with the so-called Koyimsi of Zuñi. These Mud Heads wear a close-fitting helmet-like mask to which are tied small balls filled with corn or seeds, making them look as if they had huge wens on the head, eyes, and mouth.

It is customary for the Hopi youth, on reaching maturity, to be formally inducted into the Katcina priesthood, and at that time the youths and maidens undergo the so-called flogging ceremony which has been elsewhere⁵ described. Up to this event children believe that the Katcinas are supernatural personages, but from then on they learn that these so-called supernaturals are really their own relations. They obtain this knowledge through flogging by their elders in the kivas.

One of the most important objects on the Katcina altar is the badge of the chief or, as it is sometimes called, the *tiponi*, or mother of the priesthood. This sacred emblem is the palladium of the priesthood and the symbol of its chief. It must be placed here as indicative that the altar is genuine, and is carried, in the public dance, on the arm of the chief as an emblem of his chieftaincy.

This emblem is practically an ear of corn done up in numerous wrappings of buckskin with certain prescribed feathers and herbs. Many occult powers are ascribed to it and there are many prescribed rules of handling, placing it in position on the altar, and general treatment that are rigidly observed by some priests. When not in use it is generally wrapped in cloth and hung up in some nook or corner of a dark chamber in the rear of the room in which the chief lives. "This is my mother," said an old chief to me, speaking of his *tiponi*. "It was brought up from the underworld by my ancestors where the races were born. When I die a part of it will be put over my heart as a badge of my rank."

In a full Katcina dance we have depicted the following personages: First, the sun as leader; second, a number of men dressed to represent the male (*takamu*, their men); third, six persons to represent the sisters (*manas*, maid) or the female members; one to represent the uncle, and sometimes one or more to represent the aunt. It will be seen in looking over this assemblage of relations or personations that the father is not represented, due to the fact that he does not belong to the same clan as the uncle, aunt, brothers, and daughters. In other words, in the Katcina membership there is a strict parallelism with what occurs among the living members of a clan and the personators of dancers in the masque; indicating a close likeness in conception in the Hopi mind between the ancients and the living members of the clan. Apparently the ancestral members of clans preserve

⁵ Journ. Washington Acad. Sci., Vol. VII, No. 6, pp. 149-158. 1917. Reprinted under the title "A religious ceremony of the Hopi Indians." Sci. Amer. Suppl. Vol. LXXXIII, pp. 226-227, April 14, 1917.

the same social condition as their posterity, as well as engage in the same occupations and have the same customs; the different members being indicated by symbols on their grotesque masks.

In an ancestor worship of this kind no personality appears, no particular ancestral individual or named ancestor is represented; in fact, a *Katcina* is a generalized mythical conception which can not be accurately identified, and is quite unlike the ancestor among the nations of the Old World, where this worship is a most prominent feature.

The most elaborate type of *Katcinas* are those of the *Honani* or Badger clan, whose festival may be taken as an unabbreviated form. The two great pageants of this clan are their advent in February and their departure in July; the former festival is called the *Powamu*,⁶ the latter the *Niman*. Half of the year is given up to this cult and no other great ceremony is performed in that epoch. The *Patüli-konti*, or sun serpent dramatization of the *Patki* people, which is considered in my article on Sun Worship⁷ occurs in March at the vernal equinox.

There are no other clan ancients whose advent, presence, and departure are celebrated in the elaborate pageant of the Badger clan here described, but others are sometimes represented by many actors as in such popular dances as the *Angya Katcina*, the *Heheya*, *Humis*, and others. Individual *Katcinas* as *Tcanau* (fig. 5 f) also appear, representing survivals of clan personators formerly powerful but whose living clan representatives no longer exist; their clan is too small to make any considerable representation of these personations. It is not unusual to meet these in twos or threes, wandering around the pueblos, especially at the time of the great *Powamu*, when they naturally congregate.

A striking type of *Katcinas* is known as the *Natackas*⁸ (pl. 7), who figure prominently at the celebration of the arrival of the *Katcinas* in February. They are the monsters whose masks are in the special keeping of the *Asa* clan, which came to the Hopi from Zuñi, and their appearance is confined to the East Mesa of the Hopi, there being no representation of these monsters at the Middle Mesa or elsewhere.

The masking, dress, and accouterments of the *Natackas* are shown in the accompanying plate (pl. 7). They are represented in February, at the *Powamu*,⁹ when their performance may be described as a spectacular episode. The *Natackas* make two visits to the rooms of every important householder and at the time of their first visit they

⁶ Tusayan, *Katcinas*, 15th Ann. Rept. Bureau of American Ethnology. 1897.

⁷ Smithsonian Report, 1918.

⁸ Tusayan *Katcinas*, *loc. cit.*

⁹ *Op. cit.*

demand presents, food, tobacco, or other gifts. They ask flour to bake into bread from the women of the household, and present miniature traps to men and boys, telling them to use them in snaring food for meat. They also threaten those who disregard their demands, saying, on their departure, that they will return in a few days and if the required gifts are not forthcoming they will do violence to the recalcitrant ones, cut off their heads, flog or mutilate their bodies. They brandish their knives, bows, arrows, and other weapons with which they threaten to kill those who do not furnish the presents. These monsters make the routine of all the pueblos on the mesa on their strange mission.

A few days later they return and gather great quantities of food, which they carry into the kivas. This food is cooked and devoured in the great feast which closes the festival. The fact that the number of participants in the annual celebration of the coming of the Katcinas is large, necessitates great quantities of food, which has no doubt done much to keep alive this unique episode in the celebration of *Powamu*.

The masks of the *Natackas* are shaped like the heads of alligators; one is painted yellow, one green, one red, and one white, corresponding to north, west, south, and east. They constitute a striking element in the Katcina festival but otherwise than gathering food for the celebrants are not ceremonially important.

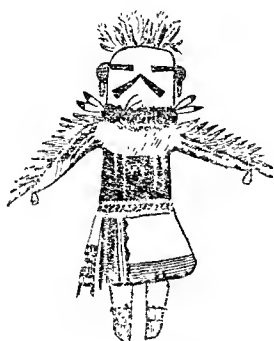
A bogey Katcina, very much feared by the children, appears in the Hopi village at the time of the great Return Katcina celebration. She is the monster who bears on her back a basket and in her hand a knife, threatening to cut off the heads of naughty children and carry them away in her basket. At her coming the children shiver and hide away in back rooms of the house. This unwelcome visitor is shown in pl. 7, the third figure from the extreme right.

The Hopi recognize quadruplets of every Katcina, differing in colors but having the same symbolism. Each cardinal direction has its characteristic color; north is yellow, west is green or blue, south is red, and east is white, and there is a Katcina for each of these different cardinal points bearing corresponding colors.

In addition to the masks which are used in the course of the yearly celebrations, many households have others, black and dingy with age, that once belonged to related clans now extinct, but are preserved as heirlooms. The symbols on these are characteristic and have a meaning to those who now own them, but are never seen in public.

In the days when the Hopi still preserved their aboriginal customs one often saw on entering a room a number of wooden images suspended from the rafters, which the Hopi call Katcinas. These images have been called idols, but a little study shows that they should be regarded as dolls bearing the symbolism of the Katcinas.

They are made in the kivas by the men and at the close of the dance celebrating the departure of these supernaturals or at other times they are given to the little girls. They are, in fact, playthings and are treated by the little girls as such. The instructive thing about them is that these dolls bear the symbolism of different Katcinas and are called by the appropriate name of the supernatural the symbol indicates. The author has seen over 200 different kinds of Katcina dolls (figs. 4-9).¹⁰



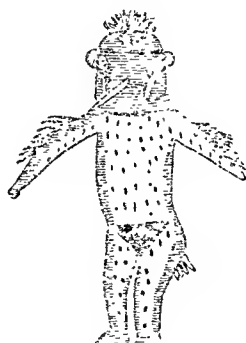
a. Red hawk.



c. Owl.



b. Bee.



d. Snipe.

FIG. 4.—Indian pictures of Bird Katcinas.

While the Katcinas show one of the best illustrations of the worship of "our others," "elder brothers," or ancestors, there are aberrant examples in other great Hopi family festivals, as for instance the Snake Dance.

One of the most numerous and powerful families now living at Walpi is the Snake clan, which claims to be one of the first that settled in this pueblo and to have migrated to the Hopi country from the north or from former habitations in the cliffs on the San Juan

¹⁰ See Dolls of the Tusayan Indians, Inter. Archiv. 1892.

River and its tributaries. The family, so a legend¹¹ says, is descended from a mythic ancestor or snake woman and has reptilian as well as human members; the snakes we see in the fields are descended from the earliest offspring of these two cult ancestors, which sprung from people of the underworld. Every two years the Snake family holds its family reunion at Walpi and at that time the reptiles are gathered in from the fields and carried by the snake men or snake



e. Humming bird.



g. Cooper's hawk.



f. Tcatau Kachina



h. Buffalo maid.

FIG. 5.—Indian pictures of Kachinas.

priests, their younger brothers, in the sight of spectators. Reptiles, or elder brothers of the clan, are supposed to have greater power to bring the rain and make the crops grow than modern priests who pray to them at the close of the family gathering of the Snake clans.

When the Snake Dance is celebrated reptiles are gathered from the four world quarters corresponding to the cardinal points to partici-

¹¹ The Snake ceremonials at Walpi. Journ. Am. Ethnol. and Archaeol. vol. iv, 1894.

pate with other members of the clan, since they are considered as elder brothers or, as legends say, descendants of a Snake Hero and Heroine, the ancestral pair which the snake and antelope priests secretly personate in their kiva where the uninitiated are denied entrance. As a matter of bodily purification the heads of the reptiles, like those of the priests, are washed and prayers are said for abundant harvests and bountiful rains for crops. The reptiles are not worshipped but regarded with reverence, for on account of their magic



a. Chicken.



c. Eagle.



b. Owl.



d. Duck.

FIG. 6.—Indian pictures of Bird Kachinas.

powers it is believed that they are capable of rendering most potent supernatural aid in obtaining material blessings. When at the close of the festival they are released, prayer meal is sprinkled on them and they are carried back to their homes and urged to "bring the needed rain."

The first parents of the Snake clan, human and reptilian, are called the Snake Youth and the Antelope or Snake Maid, both of whom are personated in the chief kiva at Walpi as described in the several published accounts of the Hopi Snake Dance. These per-

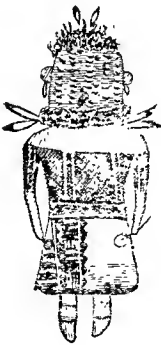
sonations have as authority the recorded legend of the Snake Hero, an account of whose adventures in the underworld when he first saw the Snake Maid and brought her a bride to the upper world is found in the author's account of the Snake Ceremonials at Walpi. These personages do not appear openly in the public exercises of the Snake Dance, but stand back of the antelope altar in the kiva where the priests with songs and prayers consecrate their prayer



e. Mocking bird.



g. Hawk.



f. Owl.



h. Wasp.

FIG. 7.—Indian pictures of Katchinas.

offerings to the rain and other gods of the cardinal points. The reptiles are not worshipped as ancestors, but as "others of the clan" who from their mysterious character and the fact that they are supposed to be more powerful than the living members of the clan, are entreated to intensify the prayers of their brethren. The ceremonials now performed as secret rites in the Antelope kiva are supposed to resemble those the Snake Hero witnessed and learned when he visited the underworld and obtained his bride.

There are three women's dances in which also a form of ancestor worship is exemplified by a cultus ancestor and ancestress; two of these are called basket dances, from the fact that the women participants carry in their hands flat basket trays characteristic of the Hopi; in the third, wooden tablets decorated with symbolic pictures are borne in the hands in the public dance. The ancestral features are shown in the character of the idols representing the cult hero and heroine of the priesthood that are erected at the time of these dances in the sacred rooms or kivas. The heroine at least is personated likewise in the public dance, but the image of the same is seen only on the secret altars of the priesthood. These three dances are known as the *Owaküiti*,¹² the *Lalakonti*,¹³ and the *Mamzrauti*,¹⁴ the last mentioned, celebrated with great eclat 25 years ago, having now become extinct at Walpi. The three dances above mentioned always



FIG. 8.—Indian picture of Turkey
Cock Katsina.



FIG. 9.—Indian picture of Buffalo
Katsina.

occur in the autumn, generally just before the close of the Hopi year, and are closely followed by the New Fire Ceremony in November, when a new year begins. Each has its own altar and paraphernalia and lasts nine days, the first eight of which are devoted to secret rites and ceremonials. The significant feature in their relation to ancestor worship is that each has its own cultus hero and heroine, and, most important of all, there is an idol on the altar representing the goddess of Germs, practically a symbolic representation of a gigantic ear of corn.

In the preceding pages we have indicated different types of the worship of "others" of the clan which, for want of a better name, has been called ancestor worship. We may classify the types into three groups: (1) Katsinas or personations of the clans that people

¹² The Owaküiti altar at Sitcomovi pueblo. Am. Anthrop., n. s. vol. lii, No. 3. 1901.

¹³ The Lalakonti: A Tusayan Dance. Am. Anthrop., vol. v, No. 2. 1892.

¹⁴ The Mamzrauti: A Tusayan Ceremony. Am. Anthrop., vol. v, No. 3. 1892.

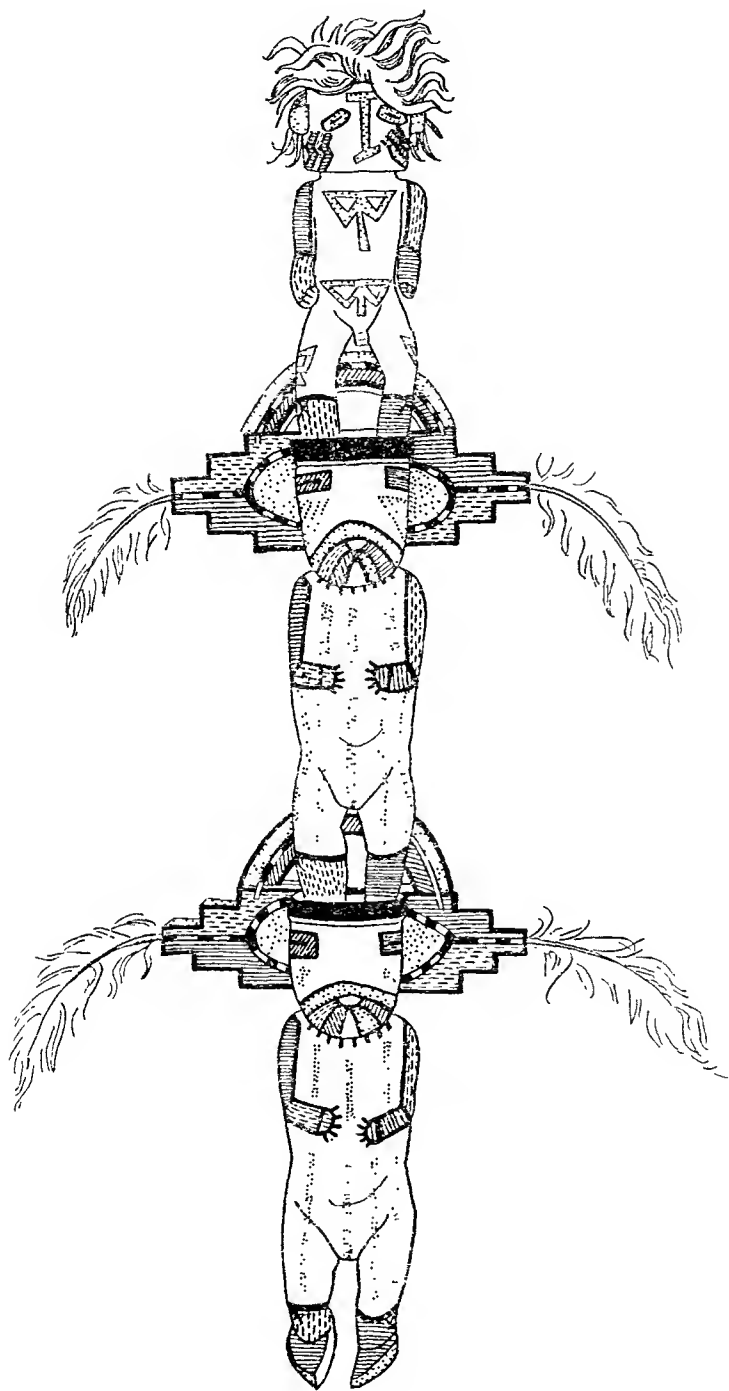


FIG. 10.—Doll of Heheya Katsina and two Corn Maids.

the underworld; (2) Elder Brothers, personated by reptiles or descendants of the first offspring of the cultus hero and maid, the Snake-Antelope woman, the mythic ancestress of the Snake-Antelope clan; (3) the cultus maid of the women's societies, who dance with baskets or tablets bearing symbols of many clans. This cultus maid is in reality the Corn Maid (fig. 10) or the supernatural who brought maize to the Hopi. A complete account of her festival should not be considered under ancestor worship, as it would furnish enough material for a special article which would take one too far afield to consider at this time. One instinctively thinks, in studying the Katcinas, of the Latin lares and penates, the former of which appear to have been deified ancestors, and of the many house spirits which were formerly worshipped among many races, survivals of which appear in folklore. Although the theory that the lares were deified family ancestors is not accepted by all students, there is good reason to believe their worship is a very ancient one, more so than that of the great nature gods.

THE INDIAN IN LITERATURE.¹

By HERMAN F. C. TEN KATE.

INTRODUCTION.

Many peoples of Asia, Africa, Oceania, and America have been the subjects of romance and poetry. Among these the American Indian and his country occupy a prominent place. The Indian has been the subject perhaps as often of novelists and poets as of artists, but, on the whole, the latter have been more successful in depicting his true character.

Among the exotic races of man the "Redskin" might well-nigh be called classical. From the very first a great attraction and charm went out from the Indian of the wilderness not less than from the brown Polynesian. Taken in the widest sense, no people are generally better known than the heroes of Fenimore Cooper and Gustave Aimard. The courage and other martial virtues of the Indian, his tragic history, have appealed for more than a century to the interest and sympathy of cultured society in North America and Europe. And yet that same society, even in America, knows really very little about him. It must be borne in mind, however, that it is only during the last thirty-five or forty years that ethnologists have begun to study the Indian and his psychological characteristics on a scientific basis.

Although exotism in literature with regard to other countries and peoples has been more than once the subject of criticism and comment—e. g., the works of Pierre Loti and Lafcadio Hearn—a special analytic and synthetic study of the American Indian has never been written, so far as I know. Even in such a pretentious work as *L'Éxotisme* of Cario and Régismanset (2^d edit., Paris, 1911) only six authors on Indian literary subjects are mentioned. The reader looks in vain for Longfellow, Bandelier, Remington, and other well-known names.

In view of the scanty data concerning this subject I shall try briefly to review the principle literary works in which the Indian

¹ Condensed translation and abstract of papers published in the Dutch magazines *De Gids*, 1919, and *De West-Indische Gids*, 1920.

figures as the hero. I omit all books of travel, works on geography, ethnology, and history with regard to the Indian and his surroundings, however great the merit of some of these works may be, and confine myself to purely literary works only. My standpoint, however, is not that of a literary reviewer but of an ethnologist and geographer who by personal experience is more or less familiar with the Indian and his country. Although the scientific standpoint prevails, I can not wholly ignore the literary merits which some of the books under attention undoubtedly possess. Literary works of particular value for the knowledge of the Indian and his surroundings have, of course, been more carefully reviewed than those of little or no scientific value. This review is far from exhaustive, particularly with regard to Central and South America. Moreover, several writers, old and modern, had to be omitted or simply mentioned, as their works were not available at the time of writing the paper. For instance, James Hall, Thorpe, Murray, Ruppius, Lummis, and a few others had to be passed over in silence. A certain class of popular writers was intentionally ignored because their books are absolutely valueless, or even misleading, from the ethnologist's point of view. So far as European authors are concerned, the review is fairly complete. It covers a period of about 120 years (1799-1916). Any older works are not taken into consideration.

North and South America I have treated separately. The North American Indian has been much oftener the subject of novelists and poets than his southern brother.

Although the Eskimo are not Indians, they nevertheless belong to the American natives, and, besides, they have several traits in common with the Indians. For this reason the poem of Emil Bessels, on account of its considerable scientific value, could not well be omitted.

Nearly half of the 37 writers here noted are born or naturalized North Americans. Only 1 is of South America.

So far as possible, the review is arranged according to the chronological order in which the different works appeared, but, for obvious reasons, this principle could not always be followed.

I.

The first American novelist of note who wrote about Indians seems to have been Charles Brockden Brown (1771-1810) in *Edgar Huntley*, which book appeared in 1799. From the ethnologic point of view it is of no importance. Brown patterned his Indians after the more or less degenerate Indian loafers then to be found in the vicinity of certain New England towns. But Brown brought some-

thing new before the public, "figures unfamiliar in literature—so unfamiliar, indeed, that Brown himself does not seem quite at home with them."

Next comes Washington Irving. In his *Sketch Book*, which appeared for the first time in 1819, there are two fine chapters on Indians—*Traits of Indian Character* and *Philip of Pokanoket*, an Indian Memoir. On the whole, Irving's description of Indian characteristics is faithful and sympathetic, although necessarily somewhat superficial. The latter sketch, which is the more important, is an eloquent memorial to that great Indian patriot, Philip of Pokanoket (Metacom or King Philip), the soul of the war against the English in 1675–76. Irving writes, i. a. :

With a scanty band of followers, who still remained true to his fortunes, the unhappy Philip wandered back to the vicinity of Mount Hope, the ancient dwelling of his fathers. Here he lurked about like a specter among the desolated scenes of former power and prosperity, now bereft of home, of family, and friend.

Further on he says :

Even in this last refuge of desperation and despair a sullen grandeur gathers round his memory. We picture him to ourselves seated among his careworn followers, brooding in silence over his blasted fortunes and acquiring a savage sublimity from the wildness and dreariness of his lurking place. Defeated but not dismayed, crushed to earth but not humiliated, he seemed to grow more haughty beneath disaster and to experience a fierce satisfaction in draining the last dregs of bitterness.

More widely known than the Indian work of Brown and Irving are the frontier romances of James Fenimore Cooper. Among the older writers he stands foremost. Several of his works have been translated into various languages, including Dutch.

Cooper, as we know, passed his youth, in the latter part of the eighteenth and early nineteenth centuries, on what was then the frontier, near Otsego Lake, New York. Those days left an indelible impression upon him, and there is no doubt that some characters of his novels, among the whites at least, were depicted from real life. It is, however, somewhat doubtful whether he personally had much intercourse with Indians. It would seem that the greater part of what he tells his readers about the eastern Indians—Delawares, Mohicans, Hurons, and Iroquois—is borrowed from frontiersmen, colonists, and hunters, and also from various books. Properly speaking, Cooper, like many novelists after him, has given rather a composite description of Indian characteristics, manners, and customs than an exact account of any tribe in particular. Although, on the whole, he did not try to idealize the Indians, he nevertheless, appreciates their good qualities. The Mohican chief, Chingachgook, and his son, Uncas, as painted by Cooper, represent the Indian in his noblest

expression. The Huron, Magua, and his fellow tribesmen show the Indian's darkest side.

Space does not permit me to analyze the different novels of Cooper which appeared between 1823 and 1841, such as *The Pioneers*, *The Last of the Mohicans*, *The Deerslayer*, *The Prairie*, and *The Pathfinder*, but a few critical remarks must be made, particularly with regard to *The Last of the Mohicans*, which is generally considered his masterpiece. Cooper does not discriminate enough between the different Indian tribes and their subdivisions. For example, too little distinction is made by him between Delawares and Mohicans. Uncas,² the Mohican, is for Cooper, at the same time, "a son of the great Unamis" (Turtle). This is, of course, absurd, as the Unami constituted the principal of the three subtribes—or, according to Morgan, the three gentes—into which the Delawares were divided. The Mohicans were a distinct people.

Concerning the identification of the Mohican, there exists, or existed, a great confusion, not uncommon in American tribal synonymy. Briefly stated, there were; or still are, two different groups of Mohican, each of which had its distinct dialect. One of these groups lived on the upper course of the Connecticut River, and the other one on the upper Hudson as far as the vicinity of Lake Champlain. Cooper's Mohican seem to belong to the latter group. But they were certainly not the last Mohican, even in 1757, the year in which the romantic events painted by him are supposed to have happened. Of the Connecticut Mohican about 100 were still existing in 1904, although largely of mixed blood. With regard to the Mohican formerly of the Hudson River region, Michelson³ a few summers ago collected some linguistic material among the remnant then residing at Green Bay, Wis. The logical inference which we must draw from the foregoing is that the pathetic lament of Chingachgook: "I am on the hilltop and must go down into the valley; and when Uncas follows in my footsteps there will no longer be any of the blood of the Saganiores, for my boy is the last of the Mohicans"—can not be taken literally.

From Cooper's novels the reader might infer that the Mohican and Delawares spoke the same language. Hawkeye, for instance, always speaks Delaware with Chingachgook and Uncas. This is not the fact. Moreover, the Mohican language is more closely related to Pequot than to Delaware.⁴

² It is obvious that Cooper's fictitious Uncas has nothing in common with the historic Uncas, a Mohican chieftain of Connecticut who died about 1683. Nevertheless there seems to exist some confusion with regard to the two. Cf. *Handbook of American Indians*, part 2, Bur. Am. Ethnology, under Uncas; see also Unami, Mohican, and Mohegan in the same work.

³ *Internat. Journ. of Am. Linguistics*, vol. 1, p. 57. New York, 1917.

⁴ Michelson, loc. cit.

We shall close these critical remarks with another instance of Cooper's ethnological errors. In his *Wept of Wish-ton-wish*, the events of which novel are supposed to occur about 1666, we are told that the New England Indians scalped their enemies. They did not. Thanks to Friederici's researches⁵ we now know that at the time of America's discovery the area of the scalping custom was very limited, and that this practice spread only later and gradually, a result to which the whites largely contributed.

Notwithstanding the foregoing criticism, Fenimore Cooper stands unsurpassed as a writer of Indian and frontier stories of the seventeenth and eighteenth centuries; and as a truthful painter of scenery very few Indian novelists equal him.

During Cooper's life another American writer, William Gilmore Simms, wrote a few novels concerning the then southeastern frontier. About 1825 he visited the region of the Mississippi with his father, who had previously been among the Cherokee and Creek Indians, from whom he had brought back wonderful tales which also must have inspired the future author of *Guy Rivers*. This novel, which appeared in 1834, was shortly afterwards followed by a second one, *The Yemassee*, which is better known. The influence of Cooper on Simms is evident, but although Simms was the author of several other works also, he never reached the standard of Cooper.

The poem, *Mogg Megone*, of John Greenleaf Whittier, which appeared about 1835, is of quite a different character. It relates to a tragic episode of Colonial history in 1724: the massacre and burning by English colonists of the Catholic mission of Father Râle at Norridgewock, Me., in which *Mogg Megone*, an Abnaki Christianized chief and many of his followers perished.

With the exception of certain novels of Cooper and Aimard, and of Chateaubriand's *Atala*, no literary work on Indians is more widely known than *The Song of Hiawatha* by Henry W. Longfellow. Published for the first time in 1855, it has been wholly or partly translated in several languages, even in Latin, and including a Dutch rendering by J. J. L. ten Kate. Longfellow did not himself collect in the far West the material for the *Song*, but borrowed, as we know, from various Indian traditions told by Schoolcraft in his *Algic Researches and History, Conditions, etc.* of the Indian Tribes in the United States, as well as from Heckewelder, Catlin, Mary Eastman, and others. His personal acquaintance with Indians was limited to the few from the West whom he saw and met at Boston. In our day we know who and what *Hiawatha* was, but when Longfellow wrote his *Song* we did not. Therefore the poetical descriptions of *Hiawatha's* origin, position, and character are a curious

⁵ *Skalpieren und ähnliche Kriegsgebräuche in Amerika*, p. 17. Brunswick, 1906.

mixture of misconception and fallacies. Hiawatha was undoubtedly a historical figure, but in Longfellow's mind was not only identical with Manabozho (Nanabozho, Michabo), but also with Teharonhiawagon. These names, however, do not designate historical or even mythico-historical figures, but anthropomorphic deities. Manabozho, with his many synonyms, belongs to the Algonkin pantheon and in particular to that of the Ojibwa, and Chibiabos (Chipiapoos) is one of his brothers, while Longfellow makes him a kind of bard and a friend of Hiawatha. Teharonhiawagon resembles in the main Manabozho but belongs to the mythico-religious cycles of the Iroquois. Longfellow makes Hiawatha an Ojibwa of Lake Superior, while it is beyond doubt that he was either a Mohawk or an Onondaga of central New York, while Hiawatha's mother bears in the Song a Dakota name, Wenonah. Mudjekeewis, the West Wind, is not only Hiawatha's father, but also his grandfather. The confusion is made still worse because the place of action of the Song is put on the southern shore of Lake Superior. It would be very easy to give more instances of the many ethnologic errors which the poem contains. Nevertheless, the spirit of the Song is on the whole decidedly Indian. Its well known literary charms need not be recalled here. To my mind, Hiawatha's Wooing, The Ghosts, and The Famine are among the best parts.

Two other minor poems of Longfellow dealing with Indians may be mentioned here: The Burial of Minnisink and To the Driving Cloud. The latter relates to an Omaha chieftain visiting an American city.

Fenimore Cooper was hardly 2 years old when the young French viscount François René de Chateaubriand visited North America in quest of adventures and subjects for his pen. Chateaubriand's stay covered only six or seven months of 1791, and his travels probably did not extend much farther than the Ohio River. Although he undoubtedly went up the Hudson, crossed the country of the Iroquois, and visited Niagara Falls, we are in doubt as to his further wanderings. Even his *Voyage en Amérique* is very vague in this respect, and although he casually remarks that he traveled along the banks of the Mississippi, nothing is less proven. The only authentic, though very superficial, description of Indians in the *Voyage* refers to the Onondaga. As for the chapters on the manners and customs, languages, religion, etc., of Indians in general, and on the geography and natural history of what he calls "les Florides," they consist of a curious, confused mixture, obviously copied from various writers, among whom he acknowledges that he owes much to Bartram.

The principal Indian hero of Chateaubriand is Chactas, a Natchez. First he appears in *Atala*; next, though incidentally, in *René*; and

finally in *Les Natchez*. Chateaubriand says that the life story of *Atala* was told him by a Seminole, which seems very doubtful. *Les Natchez* is based on an episode of French colonial history in the first half of the eighteenth century. In writing this novel, he borrowed his data from various sources, chiefly from Charlevoix, and perhaps also from *Le Page du Pratz*. Chactas and his maiden love, *Atala*, Celuta, the Natchez wife of the unfortunate René, not to mention others of Chateaubriand's Indians, are all very unreal, psychologically untrue. Their maudlin sentimentality, as well as their frequent laments and weeping and speaking "la langue de la cour de Louis XIV,"⁶ smack of the theater. These defects are, of course, partly due to the time in which he wrote.

From the foregoing we may draw the inference that ethnologically Chateaubriand's American works can not be taken seriously. As a piece of literature, however, the tragic idyl, *Atala*, is generally considered to be a masterpiece, far superior to *Les Natchez*.

A few examples of Chateaubriand's fallacies will suffice to show his worthlessness as an Americanist.

In the Epilogue of *Atala* Chateaubriand asserts that he met (in 1791) the last remnant of the Natchez tribe near Niagara Falls, carrying with them the bones of their fathers. This, of course, is impossible, for after the defeat these Indians suffered at the hands of Governor Perrier in 1731, the Natchez scattered and mainly took refuge among the Chickasaws, Cherokee, and Creeks. Among the last mentioned tribe Swann found, in 1791, more than one Natchez village.⁷ In *Les Natchez* the names of Manitou, Kitchimanitou, Michabou, and Athaensic are frequently met with as being Natchez gods, while they are in fact Algonkin and Huron. But these blunders are not worse than the description of the great council of many tribes—Natchez, Indians from the Atlantic coast regions and Mexico, and even Eskimo being among them—which was held on the northern shore of Lake Superior; or more absurd than the appearance at New Orleans of a flotilla of canoes manned by Pawnee Indians.

He who wants to judge Chateaubriand as an ethnologist and topographer ought to compare his data with those of Doctor Swanton⁸ concerning the Natchez Indians.

Among the great German poets I know of but three who incidentally wrote about Indians. These are Schiller, Adelbert von Chamisso, and Nicolaus Lenau. Only the two latter visited America. Where Schiller got the motives of his *Nadowessiers Todtenlied* I do

⁶ Henri-Frédéric Amiel, *Fragments d'un Journal intime*, 9th edit., t. I, p. 132.

⁷ John R. Swanton, *Indian Tribes of the Lower Mississippi Valley*, etc., p. 253 (*Bulletin* 43, *Bur. Am. Ethnology*, Washington, 1911).

⁸ *Op. cit.*, pp. 45-257.

not know; I mention it only because of a curious blunder made by the great poet, who speaks of an Indian following the trail of the Rennthier (caribou) on the prairie in the Sioux country, which, of course, is absurd. Chamisso's Indian subjects have no connection whatever with his visits to the American coast. They date from 1828-1830, and bear the titles of *Rede des alten Kriegers Bunte-Schlange im Rathe der Creek-Indianer*, and *Das Mordthal*. The former poem is possibly based on history, for Spotted Snake complains in it of the unjust and cruel treatment of the Creeks by the whites. The latter poem refers to a tale which appeared in the *North American Review*.

I shall speak later on of Chamisso's poetical rendering of another South American tragedy, the best of the three he wrote.

When such a poet as Lenau visited the United States in 1832 it was but natural that the sea, the forest, Niagara Falls, and the tragical fate of the Indian appealed to him, and that he chose them as subjects for his songs. *Der Indianerzug* and *Die drei Indianer* deserve to be mentioned. With regard to the former poem, "*Indianer sind's, die von der Heimath scheiden*," the forest along the Susquehanna River resound with laments as the Indians are forced by the white settlers to leave their country. After their first halt under the high oaks, at dawn a red glare can be seen at the far horizon, for the forests, left only yesterday, are on fire. The white intruder has begun his work of devastation.

The second poem is even more sad. Three Indians, an old man and his two sons, robbed of everything by the whites except "*im Herzen todlich bittres Hassen*," while singing their death song commit suicide by throwing themselves with their canoe into the thundering falls of Niagara.

III.

Of a very different class of writers on Indian subjects are those often called, more or less justly, writers of fiction for the young. They are comparatively quite numerous, and some of them have been (and some perhaps are still in Europe) as popular as Fenimore Cooper. The best known are Gustave Aimard, Gabriel Ferry, Benedict Henry Revoil, de Wogan, Mayne Reid, Gerstäcker, Armand, Ruppius, and Möllhausen. Taken collectively, they were especially in vogue between the years 1850-1870. On the whole, the literary merits of these novelists are rather slight. Ferry and Mayne Reid are among the best. From the ethnological and geographical standpoint most of these books are absolutely worthless, even misleading, and the rest of little value. It seems doubtful to me whether some of these nine men really visited the Far West and the Indians they describe.

Aimard was a very prolific writer. Among his many books I mention only *Les Trappeurs de l'Arkansas*, *Les Chasseurs d'Abeilles*, *Coeur de Pierre*, *Balle-Franche*. They were translated in several languages.

Of Gabriel Ferry (pseudonym of Lonis de Bellemarre) the fascinating novel, *Le Coureur des Bois*, and the Mexican story, *Costal l'Indier* must be mentioned.

Among the frontier romances of the Irish captain, Mayne Reid, *The Scalp Hunters*, *The Desert Home*, and *The Headless Horseman* stand first. His topographical descriptions, as of the high dry plains and the chaparral of western Texas, are particularly truthful.

Friederich Gerstäcker, once the most popular *Reiseschriftsteller* of his time, notwithstanding his many travels in North and South America, has written very little about Indians worth mentioning.

Strubberg, under the pseudonym of Armand, wrote several books, partly based on his travels and adventures, among them *Bis in die Wildniss und Amerikanische Jagd- und Reise-Abenteuer* (2d edit. Stuttgart, 1876).

Ruppis, another German novelist, wrote, among others, *Der Prairie-Teufel*, which has been translated in Dutch.

Baldwin Möllhausen, a companion of Whipple and Ives in the western wilds, was not only a writer of numerous books of travel, illustrated by himself, but also of many novels dealing with American subjects. In some of these Indians figure. On the whole his descriptions are quite trustworthy. Although he belonged to an earlier generation, his work reaches into the twentieth century, for in 1904, when nearly an octogenarian, he published a collection of essays under the title of "*Bilder aus dem Reiche der Natur*," partly relating to Indians. The introduction to this book is a poem of some merit, in which he recalls his early life in the west among the Indians, and compares things with the new conditions more than fifty years later: a melancholy retrospect. In this poem the old traveler has before his mind's eye a "*milden Zauberabend*," when he stood on the high bluff of the Nebraska (Platte) River. At his feet the prairie stretched "*unabsehbar grün und duftig*," with the teepees and campfires and grazing horses of the Sioux—a picture of peace and poetry in the days of long ago. And at present?

Jahre sind seitdem entschwunden,
 Ueber fünfzig lange Jahre.
 Was einst Poesie der Wildnis;
 Bisonsherden, braune Jäger,
 Lust'ger Ritt auf Tod und Leben.
 Ist verwandelt und zerstoben
 Vor dem Hauch des Eisenrosses,
 Feuer fressend, Funken schnaubend.

Two of Edward S. Curtis' books ought perhaps to be mentioned here, as they also were written for youthful readers. From the ethnologist's point of view, however, there is such a marked contrast between these books and those of Aimard and similar writers, that one cannot very well class them together. Moreover, Curtis' work is much more recent and will be briefly noted later on.

IV.

To American readers much need not be said about the life and works of Joaquin Miller. I shall only bring to mind here that in several of his poems he sings of the West and the Pacific coast from Oregon to Nicaragua, and in these poems the Indian not infrequently figures. Much of his poetry and prose work was published in London between 1871-1878.

In *The Last Taschastas*, which appeared in the volume, *Songs of the Sierras*, Miller describes the "war chief's daughter" as follows:

Taller than the tassel'd corn,
Sweeter than the kiss of morning,
Sad as some sweet star of morn,
Half defiant, half forlorn.

In the same poem an Indian brave is depicted thus:

His breast was like a gate of brass,
His brow was like a gather'd storm;
There is no chisel'd stone that has
So stately and complete a form,
In sinew, arm and every part,
In all the galleries of art.

As in Miller's poems, we find truth and fancy also mixed in his prose works, such as his *Life Amongst the Modocs*. Ethnologically both have hardly any value. Nevertheless his descriptions of western types, scenes, and scenery in this book, as well as in several of his western poems, are often interesting, bearing the stamp not only of a strong individuality but also of things really seen and felt.

On the well-known novel, *Ramona*, of Mrs. Helen Hunt Jackson I need not dwell either for American readers. While I fully acknowledge the noble aim and effort of the authoress of *A Century of Dishonor*, as well as the great merits of *Ramona*, the California Mission Indians she depicts hardly interest the ethnologist, deeply as their sad history may move the philanthropist.

Although much has been written about Tecumseh, I know of only one literary work concerning the great Indian patriot, namely, a drama, *Tecumseh*, by Charles Mair (London, 1886). On the whole, Mair would seem to be historically correct, with the exception of certain dramatis personæ and of some assertions contained in the explanatory notes. Moreover, the way in which his Indians speak sounds rather un-Indianlike, but possibly this could not well be

avoided in English. Tecumseh's monologue embodying his favorite idea may serve as an illustration:

From vales and rivers which were once our own
 The pale hounds who uproot our ancient graves
 Come whining for our lands with fawning tongues,
 And schemes and subterfuge and subtleties.
 O for a Pontiac to drive them back
 And whoop them to their shuddering villages.
 O for an age of valor like to his,
 When freedom clothed herself with solitude,
 And one in heart the scattered nations stood,
 And one in hand. It comes. And mine shall be
 The lofty task to teach them to be free—
 To knit the nations, bind them into one,
 And end the task great Pontiac begun.

Ethnologically the drama is of no importance.

From the scientific standpoint the work of the writers whom I have briefly reviewed in the foregoing pages dwindles into nothing compared with the works of which I shall presently give a short summary. One might say that with Frank Hamilton Cushing's *My Adventures in Zuñi* (the *Century Magazine*, 1882-83) another phase begins in American literature with regard to the Indian. To this period belong also Bandelier, Miss Proctor, Mrs. Ryan, Remington, and Curtis.

Cushing, as it is well known, had an excellent literary style, rare indeed among men of science, but only two of his publications can be classed as really belonging to our subject. In the *Adventures* he relates some of his first impressions and experiences at Zuñi. We have to do with delightful sketches of daily life in the pueblo and of the character of its dusky inhabitants. The value of the articles is enhanced by excellent illustrations, due to the pencils of Farny and Metcalf.

The way in which even trivial things of Indian life are described and Indian thoughts rendered by Cushing is far from common among ethnologists. Twice it was my privilege to stay with Cushing at Zuñi, which puts me in a position to vouch for the truthfulness of these magazine articles, from which I shall only quote the following translation of a Zuñi winter folk tale:

The rattle-tailed serpents
 Have gone into council;
 For the God of the Ice-caves
 From his home where the white down
 Of the wind in the north-land
 Lies spread out forever,
 Breathes over our country
 And breaks down the pine-boughs.

Strictly speaking, the collection of Zuñi Folk-Tales, which was edited in 1901 after Cushing's death, does not belong to our subject. An exception has been made, however, on account of the literary style in which they are rendered. Maj. J. W. Powell, who wrote the introduction to this work, justly said:

Under the scriptorial wand of Cushing the folk-tales of the Zuñis are destined to become a part of the living literature of the world, for he is a poet although he does not write in verse.

Cushing, indeed, could think like the Indians who made these myths; he could speak like their priests and prophets as probably no white man before or after him ever could. Space forbids any quotations from this interesting work.

The well-known archeologist, Adolph F. Bandelier, treated not only of the legends concerning El Dorada, dating from the "conquista", in his book, *The Gilded Man*, but he also wrote an excellent Indian novel, *The Delight Makers*. The first edition was published in 1890 at New York and a second, illustrated edition, with an introduction by Chas. F. Lummis, appeared in 1916. My review refers to the first edition. Bandelier, too, was a Pueblo familiar, who spent considerable time in the Southwest, and whose many-sided talents led him to write this novel. The effort to idealize the Indian, so common among older writers, is lacking in Bandelier's romantic story, in which he endeavors never to leave the solid ground of archeologic and ethnologic facts. Although the plot is his own, some of the scenes he describes were witnessed by himself at Cochiti. The time of the story is not actual, but is set long before the discovery of America, in what is now New Mexico, and mainly in the narrow canyon of Tyuonyi, the Rito de los Frijoles of the Spaniards. The Indians of those bygone days apparently did not differ much from the present Pueblo Indians who, Bandelier says, "are at heart nearly the same Indians we found them in this story." The dramatis personæ, of course, are only Indians, belonging to the Queres and Tehua tribes, who at that period dwelt chiefly in caves and upon cliffs.

The title of Bandelier's novel is a translation of Koshare, the name of a religious-social organization among the Queres, which was common also to Pueblo tribes, and is still in existence. The business of the Koshare consists mainly of jokes and grotesque dances at public performances which take place in summer and autumn in connection with the prayers for rain. But the *Delight Makers* play also a political part in Pueblo society, which leads to much enmity. Another important element consists of the clans with their fixed laws and reciprocal petty jealousies. The primitive religious ideas and the numerous performances connected with them, the belief in

witches, and many other superstitions, would make the life of these Indians unbearable if it were not for their innate carelessness and naive confidence in "Those Above"—Shiuna. Of all this and much more with regard to ancient Pueblo society Bandelier tells us through the many different actors in his novel. All of them can not be mentioned here; suffice it to say that they are all drawn from nature, like Topanashka, the great war chief of the Queres and the father of Say, a woman suspected of witchcraft; like Shotaye, the lonely buxom herborist; Zashue, Hayone, the Don Juan of Tyuonyi; Okova and Mitsha, the young lovers, and several others.

Among the best and most interesting parts of *The Delight Makers* I reckon the description of the great night council of clan representatives in the estufa, where questions about irrigation and the division of lands are discussed (Ch. XI). What happens on a sunny day upon the wooded mesa above Tyuonyi is also very well described (Ch. XIV and XV), namely, the meeting of Shotaye with Cayamo, a Tehua warrior, witnessed by Topanashka. At the same time the hunting of wild turkeys by a mountain lion and the curious behavior of the crows during the hide-and-seek scene of Topanashka and his invisible enemies show an extraordinary gift of observation in Bandelier. The same remark applies to the description of the wounding and death of Topanashka, the chapter in which the writer tells of the ill-fated campaign by the Queres against the Tehua of the Puye is very instructive with regard to Indian warfare and warrior psychology.

Notwithstanding the great ethnologic value of *The Delight Makers*, I am obliged to make a few critical remarks. Since Bandelier wrote his novel, our knowledge has considerably increased, for which reason he can not well be held responsible for the following mistakes: First, he mentions the Navaho or Dinné (Tinné) as being enemies of the Queres in those very remote days. Moreover, the Navaho youth, Nacaytzushe, is one of the characters in Bandelier's plot. We know now that the origin of the Dinné, according to their own tradition, dates back less than five centuries, namely, probably about the beginning of the fifteenth century. Hodge⁹ says that the arrival of the forefathers of the Navaho in San Juan Valley did not occur before the second half of the fifteenth century, and not until the seventeenth century were they strong enough to make war on other tribes. Now Bandelier is explicit in saying that the Tyuonyi Valley was already deserted "centuries previous to the advent of the Spaniards," and that his story "occurred much anterior to the discovery of America" (p. 4.)

⁹ F. W. Hodge, *The early Navaho and Apache* (*American Anthropologist*, vol. VIII, 1895, pp. 223 seq.); also, art. *Navaho* in *Handbook* quoted, part 2.

As the Spaniards did not arrive in New Mexico until 1539, and as America was discovered in 1492, it follows logically that in this case synchronism is out of the question.

Furthermore, it is very doubtful whether the Navaho knew of scalping in the time of Bandelier's novel, regardless of the question whether they really existed as a distinct tribe at the same time as the Queres of Tyuonyi. In my criticism of Cooper I have already drawn attention to the fact that at the advent of the whites in America the area of the scalping custom was comparatively limited. It would seem that at that period the practice was unknown west of the Mississippi. Moreover, even if the Dinné did scalp, the custom was not very general among them. They probably learned it from other hostile tribes, like the Pueblos. It is even open to doubt whether the Queres and Tehua knew anything about scalping before the discovery of America.¹⁰ We are forced to draw the conclusion that Bandelier errs when, in his novel, he makes the Navaho scalp an old woman from Tyuonyi as well as Topanashka. And probably our author is equally mistaken when he represents his Tyuonyi and Puye warriors as scalp hunters. In describing the shield of Cayamo, Bandelier says that its decoration—a green crescent and four red crosses—had “no heraldic significance,” being “but the creation of fancy or taste.” This is very improbable. If we may judge from the results of investigations by James Mooney into the heraldry of war shields (of the Kiowas) we can safely believe that shield decoration among the ancient and present sedentary Indians of the Southwest also had and has a deeper significance.¹¹

The foregoing remarks show how difficult it is to write an ethnologic novel answering to the requirements of science. If a specialist like Bandelier could make mistakes, it is obvious that other writers much less familiar with their subject must inevitably err when they venture to treat of Indians in literary works.

Miss Edna Dean Proctor's poem, *The Song of the Ancient People*, also relates to the Pueblo Indians, more particularly the Zuñis and Moqui (Hopi), both, we might say, harmoniously blended together in treatment. John Fiske wrote the preface and the “Zuñi familiar,” Cushing, a commentary, indorsements which vouch for the ethnologic value of the poem. Cushing, for instance, speaks of its “strict fidelity of statement” and says that it is “ancient in spirit and feeling.” *The Song of the Ancient People* was published in 1893 by the Riverside Press at Cambridge, Mass., with illustrations by Julian Scott. In it Miss Proctor brought together much valuable material concerning the religion, mythology, folk-lore, manners,

¹⁰ Cf. Friederici, *Skalpierten*, etc. pp. 13–14.

¹¹ Art. *Heraldry and Shields* in *Handbook* quoted.

customs, etc., of the Pueblo Indians, which she couched in a form of high literary value. The following quotations will give an idea of this excellent poem:

We are the Ancient People;
Our father is the Sun;
Our mother, the Earth, where the mountains tower
And the rivers seaward run . . .

Of the Corn-maids she sings:

The dews that guard the Corn-maids.
And the fields keep fair to view;
But the Rainbow is false and cruel,
For it ends the gentle showers,
And the opening leaves and the tender buds
Like the ruthless worm devours,
And still its stolen tints are won
From the blanching, withering flowers . . .

With regard to Po'-shai-an-k'ya, whose role somewhat resembles that of Hiawatha, this kind of Demiurgus, according to tradition, returned to Shi-pa-pu-li-ma, "the mist enshrouded city," after he had performed his task; which the poet renders thus:

His voice was sweet as the summer wind,
But his robe was poor and old,
And, scorned of men, he journeyed far
To the city the mists enfold,
.
Unseen, as the summer wind departs,
He vanished in mist away!

Some verses of the Song are full of pathos, rendering the lament of a vanishing people:

Words are dead and lips are dumb
Our hopeless woe to speak.
For the fires grow cold, and the dances fail,
And the songs in their echoes die;
And what have we left but the graves beneath,
And above the waiting sky?

And further:

Of the grandeur of our temple-walls
But mounds of earth remain,
And over our altars and our graves
Your towers rise proud and high!

Still another American woman writer has been inspired by the romance of the Southwest, namely, Mrs. Marah Ellis Ryan, who wrote the *Indian Love Letters* (1907)¹² and *The Flute of the Gods*

¹² A Dutch free translation of these Letters, with introduction and explanatory notes, by Doctor ten Kate, was published in *De Indische Gids* of 1920 at Amsterdam.

(1910). Both works relate to the Hopi; the former in modern times, the latter during the advent of the Spaniards. Ethnologically, Mrs. Ryan does not reach the high standard of Miss Proctor, but she also is undeniably a poet, although she does not write in verse. A feeling of deep sympathy with these gentle, interesting Indians, and sadness over their fate, pervades the work of both these writers.

The short life story of Sé-kyäl-êts-téwa (Dawn Light), the hero and "writer" of the Love Letters, is the melancholy story of many young Indians educated in the East and sacrificed to a principle. A year after his return to Walpi, Sé-kyäl-êts-téwa writes defiantly to the American maiden with her "eyes of turquoise," whom he loves in secret:

Yes! I am again the Indian! From the mocassin of brown deer skin to the head band of scarlet there is not anything of the white man's garb to tell your friends that I was a player in the University team, who for a little while was called by a white man's meaningless name, and who sat beside you on the sand dunes of the Eastern Sea a year ago.

I sit alone now and write this on a sand dune under Arizona's skies, at the foot of old Walpi's cliffs . . .

In the sand dunes there is always silence; a suggestion of a vast desert of immeasurable silences where everything human can be buried and forgotten.

The white shells, gathered by you and given to me in jest that day to make a necklace for an Indian maiden, are on the stone shrine, centuries old, on a wonderful mesa.

They keep company with the baho (plume prayer sticks) of our primitive religion. The God of the Skies guard them there.

Space forbids more quotations as well as a detailed synopsis of the Letters. Suffice to say that the end of Sé-kyäl-êts-téwa is tragic. With shattered hopes he is continually fretting, giving vent to his feelings in numerous letters to his lady love and finally dies of tuberculosis. An Indian girl, rival of the "Maid of the Moon Song," remains to mourn his loss.

Dawn Light is a kind of Chactas (*vide infra*), but much less theatrical, a sort of Indian Werther. Mrs. Ryan undoubtedly poured out much of her own soul in these "letters" which, however, do not quite solve the problem whether potentially a highly educated Indian is capable of expressing his feelings in the way that Sé-kyäl-êts-téwa does.

Mrs. Ryan's descriptions of Hopi land, with its high mesas and deep canyons, its glorious sunsets, and moon-lit nights, are particularly truthful and excellent.

Quite different from the works briefly analyzed in this chapter are the books of the late Frederic Remington.¹³ If Remington, perhaps, was not as great a writer as artist, nevertheless his literary products

¹³ An appreciation of Remington as an Indian painter appeared in *Anthropos*, t. VI, Vienna, 1911.

relating to Indians bear the stamp of a master who knew the West and its inhabitants well. Among other things he wrote *Pony Tracks*, *Men with the Bark on*, *Crooked Trails*, *Frontier Sketches*, and *The Way of an Indian*. I shall say only a few words about the last-mentioned work, which was published in 1906 in New York, and was illustrated by its author.

It relates to the life story of a Northern Cheyenne Indian which, in the main, might as well be the life story of a thousand other Indians of the prairie and mountain tribes from forty to fifty years ago. Although a severe critic in a position to judge of Remington's description of the Cheyennes and their ways would probably find cause for a few remarks, I think that on the whole Remington is right, and that the mentality of White Otter alias Fire Eater, the hero of the story, and of his comrades corresponds very well to that of the average fighting Indian in bygone days.

Whether we follow young White Otter on his first raid into the Crow country, from which he returns with a scalp and a few stolen horses, or see him starting on other expeditions, performing daring deeds leading to high honors among his people, the vivid descriptions by Remington are equally fascinating and Indian in spirit. The end of the old warrior and chief is tragic. At dawn, in winter, while Fire Eater and his followers are encamped in a remote canyon of the Big Horn Mountains, they are suddenly attacked by United States cavalry. In the confusion Fire Eater loses his hitherto inseparable "bat-skin medicine," an amulet which has protected him almost from boyhood. As the teepees are burned, all searching for the precious object is in vain. Fire Eater's youngest wife is killed and he retreats with his little boy into the snowy mountains a "victim of his lost medicine." The child dies from exposure, after which Fire Eater, deserted by his own people, at last "sat alone waiting for the evil spirits which lurked among the pine trees to come and take him."

Two little books of Edward S. Curtis which must be mentioned here are *Indian Days of the Long Ago* and *In the Land of the Head-Hunters*, published in New York in 1914 and 1915. Both are illustrated with excellent reproductions of Curtis's photographs, and are more particularly intended for youthful readers. The plot of each is wholly Indian. In *Indian Days* the story of KuKusim, a Salish boy, is told interwoven with abundant ethnologic material. The *Head-Hunters* are the Kwakiutl and neighboring tribes, about which much valuable information is given. The latter book found its origin in "an outline or scenario for a motion-picture drama." Hence it is, I presume, that this work has here and there something theatrical and unreal. It has, for instance, a curious effect on a reader versed in things Indian to listen to the declamatory rhetoric

of Curtis's Indian bards, and to hear that Motana and Naida, children of chiefs, address each other as "prince" and "princess." Notwithstanding these little defects both books are well written and very instructive, even for adult readers.

The posthumous work of Dr. Emil Bessels, "Aniligka "eine poetische Erzählung aus dem hohen Norden," treats, as I have already stated, not of Indians but of Eskimo. It was published by Otto Baisch (Stuttgart, 1891). Bessels, the naturalist of the ill-fated *Polaris* expedition, spent nine months among the Eskimo at Ita in northwestern Greenland. Aniligka is the pretty heroine of this poetic tale. She is portrayed from life as well as Aversuak, Ulajok and other characters of the story. Around Aniligka the poet-ethnologist centers his plot, which ends dramatically (*Der Eisgang*). Bessels also gives much attention to the description of the natural phenomena and the atmospheric conditions as the influence of these on Eskimo life is obvious. An appendix with explanatory notes of more than thirty pages renders Bessel's work, which in many respects is of great merit, especially valuable.

VI.

As already stated in the introduction, the literary works relating to the South American Indian are much less numerous, but comparatively they contain much of ethnologic value.

When Alexander von Humboldt and Aimé Bonpland visited the grotto of Atarupe on the Orinoco they found the skeleton remains of many hundreds of Ature Indians, a tribe, according to tradition, long since extinct. Except an old parrot at Maypures, no living being then understood or spoke the Ature language. Ernst Curtius, a friend of Humboldt, chose the "Aturen-Papagei" as the subject for a delightful little poem which Humboldt published in the first volume of his *Ansichten der Natur*. The following quotations will give an idea of it:

In der Orinoco-Wildniß
Sitzt ein alter Papagei,
Halt und starr, als ob sein Bildniß
Aus dem Stein gehauen sei.

Der Aturen allerletzter,
Trauert dort der Papagei;
Am Gerstein der Schnabel wetzt er,
Durch die Lüfte tönt sein Schrei.

Einsam ruf er, unverstanden,
In die fremde Welt hinein;
Nur die Wasser hört er branden,
Keine Seele achtet sein.

Humboldt's journey in South America also indirectly inspired Adelbert von Chamisso, who wrote the poem, *Der Stein der Mutter oder der Guahiba-Indianerin*. It dates from 1828, and is based upon a historical tragedy narrated in Humboldt's *Voyage aux régions équinoxiales*. It relates the persecution and martyrdom of an Indian mother and her two children at the hands of fanatical Spanish priests:

Am Atabapo's Ufer ragt empor
Ein Stein, der Stein der Mutter, wohlbekannt
Dem Schiffer, der dem Ort zur Rast erkor.
Etc., etc.

During his travels in the Orinoco region, Alfred Russel Wallace spent in 1851 considerable time at Javita, among the Baniva, or Maniva Indians, an Arawakan tribe. It is the same Javita which is mentioned in *Der Stein der Mutter*. By way of pastime during lonely evenings, Wallace wrote in blank verse a truthful and pretty description of this place and its dusky inhabitants. This poetic sketch appears in extenso in chapter IX of his *Travels on the Amazon and Rio Negro* (London, 1853).

The following selections are characteristic:

There is an Indian village; all around.
The dark, eternal, boundless forest spreads
Its varied foliage.

They pass a peaceful and contented life,
These black-haired, red-skinned, handsome, half-wild men.

And after a comparison between the so-called civilized, ever-toiling whites and the easy-going Indians of Javita, Wallace concludes:

Rather than live a man like one of these,
I'd be an Indian here, and live content
To fish, and hunt, and paddle my canoe,
And see my children grow, like young wild fawns,
In health of body and in peace of mind.
Rich without wealth, and happy without gold!

With regard to the South American books of Aimard and Gerstaëcker, it is best to pass them over in silence. Among the publications of the well-known Argentine politician and writer, Dr. Estanislao Zeballos, *Painé y la dinastía de los Zorros* deserves our special attention. It was published in Buenos Aires and has been often reprinted. For the following synopsis the edition of 1889 was used. *Painé Guôr* (Sky-blue Fox) was a mighty and much feared chief of the *Ranqueles*, an eastern Araucanian tribe which for scores of years terrorized the province of Buenos Aires. *Painé* ruled from 1835 to 1847, being at the same time the foremost member of the military

dynasty of the Guôr. It came to an end in 1878, together with the Ranquele tribe itself, during the campaign of extermination led by General Roca.

The reign of Painé partly coincides with that of Rosas, the Argentine tyrant. Therefore the history of the Ranqueles is interwoven with the history of Argentina, and the novel of Zeballos is to a certain extent based on historical facts.

The captivity among the Ranqueles during eight long years of a young Argentine forms the nucleus of Painé. We are told of the captive's bodily and mental sufferings; of the hopeless love of the poor, ugly Indian girl, Pulquinay, for the white "cristiano," not less strong than the passion of the latter for Painé's "favorita," beautiful Panchita, herself a captive. At last, following Painé's sudden death, the lovers succeed in regaining their freedom. This romantic story is not only charmingly written, but the description of Zeballos' Indians is truthful and excellent. These are not fantastic stage Indians, but the genuine savages of the pampas, as seen by Zeballos, himself an "hijo del país." The pictures which he draws of the endless sandy or grassy plains with their placid lagoons, surrounded by reeds and bushes, and of the glorious light at dawn and sunset are equally realistic.

Another valuable book by an author who knows what he is writing about, namely, James Rodway, is *In Guiana Wilds; a Study of Two Women* (London, 1899). Of the two heroines one is a so-called "boviander," of mixed Indian, Negro, and white blood, and the other a full-blood Macusi Indian. This rather amusing novel contains many data concerning the Macusi tribe in the interior of British Guiana. Although Rodway is in the main quite right in his descriptions, he obviously errs when he calls Makunaima the "Great Spirit." The Indians of Guiana in general do not recognize a personal, all-ruling God unless through missionary influence. Walter E. Roth's researches,¹⁴ for example, leave no doubt in this respect. Makunaima is nothing else but a "hero-god," one of the twins born from the Sun, his brother being Pia. The rôle of "kenaima" the avenger, which can take at will the shape of a boa constrictor or of a jaguar, and his paralyzing effect on the mind of the persecuted Indians, is truthfully depicted.

As the title indicates, the *leitmotiv* of Rodway's story is the psychology of the two women above mentioned. Both are equally pretty, but of a very different character. Their portraits are perfectly drawn. Chloe, the mongrel, with her slight veneer of civilization, does not come up to the moral standard of "pagan" Yariko, the

¹⁴ Animism and Folklore of the Guiana Indians (30th Ann. Report. Bur. Am. Ethnology, 1915).

devoted wife of Allan Gordon, the white adventurer who is the hero of Rodway's story.

From Dutch Guiana I know of only one story relating to our subject: Tokosi of het Indiaansche meisje; Historisch-romantisch tafereel. It was written by François Henri Rikken, a Catholic missionary, and published in 1901 at Paramaribo.

On account of the literary form in which they are rendered, a small collection of delightful folk-tales from the Andine regions in Peru and Bolivia must be mentioned. It is the Drömsagor från Anderna, written by Erland Nordenskiöld, and illustrated by Hjalmar Eldh (Stockholm, 1916). This valuable contribution to Aymara folk-lore completes the list of works here under review.

CONCLUSION.

To summarize: Regardless of whether the works briefly reviewed here have any literary merit, it appears that of the thirty-seven authors noted, not more than ten, i. e., a little over one-fourth part, can be classed as having real ethnologic and geographic value. These are for North America: Cushing, Bandelier, Miss Proctor, Mrs. Ryan, Remington, and Curtis, besides Bessels for the Eskimo; for South America: Zeballos, Rodway, and Nordenskiöld. Among these the most prominent place must be assigned to Cushing, Bandelier, and Bessels; the second to Miss Proctor, Remington and Curtis, Zeballos, and Nordenskiöld.

It is very difficult to form an opinion and to classify the other writers immediately following, such as Cooper, Simms, Longfellow, Mayne Reid, and Miller. Generally speaking, from a scientific point of view, their work has only a limited value, as they deal more in ideal descriptions of Indians in general than of Indians belonging to special tribes.

The same holds good for the works which are more or less historical or poetically descriptive, including those of Irving, Whittier, von Chamisso, Curtius, Wallace, Mair, Helen Hunt Jackson, and Möllhausen.

The works of all the other writers, including Brown, de Chateaubriand, Aimard, and Ferry, have either very little ethnologic value, or oftener still, are absolutely worthless.

The value of the very best works here mentioned is enhanced by the fact that the Indians and the conditions therein described belong for the most part to the irrevocable past. The Far West—nowadays a mere meaningless expression—with its romance and terrors, has long since ceased to exist. In South America, too, conditions are rapidly changing, and the time draws near in which the wilderness and the Indian warrior and hunter will be but a myth. The ap-

proaching end of the "uncivilized" American natives finds a pathetic expression in the poem of Ella Higginson, *The Vanishing Race*:

Into the shadows . . .
.
Those last dark ones go drifting.
. . . Mutely, uncomplainingly they go.
How shall it be with us when they are gone,
When they are but a mem'ry and a name?
May not those mournful eyes to phantoms grow—
When, wronged and lonely, they have drifted on
Into the voiceless shadows whence they came?¹⁵

¹⁵ These lines apply to a beautiful picture by Edward S. Curtis at the Alaska-Yukon-Pacific Exposition, Portland, Oreg. in 1909.

LEOPARD-MEN IN THE NAGA HILLS.¹

By J. H. HURROX.

In speaking of leopard-men I should like first of all to make it clear that I have taken the word leopard as the translation of the Naga words, because it is usually the leopard that is associated with Naga lycanthropists. The tiger, however, is also so associated, as well as one or perhaps more of the smaller cats. For all of these animals there is a generic term in most Naga languages, and when a Sema Naga, for instance, speaks of *angshu* he may mean a leopard or a tiger, between which he makes no clear distinction, or even a smaller animal such as a clouded leopard, or the golden cat. The same applies to the Angami Naga word *tekhhu*. On the other hand, the Chang Nagas have distinct words, and speak of a tiger as *saonyu*, regarding the leopard, *khühkhüh*, as little less inconsiderable than a civet cat, *khüh*.

All Naga tribes seem to regard the ultimate ancestry of man and the tiger (or leopard) as very intimately associated. The Angamis relate that in the beginning the first spirit, the first tiger, and the first man, were three sons of one mother, but whereas the man and the spirit looked after their mother with the greatest tenderness, the tiger was always snarling about the house giving trouble. Moreover, he ate his food raw, while the man ate his cooked, and the spirit his smoke-dried. At last the mother got tired of family squabbles, so put up a mark in the jungle and told the man and the tiger to run to it, the one that touched it first being destined to live in villages and the other to live in the forest and jungle. By arrangement between the spirit and the man, the former shot an arrow at the mark, while the other two were racing, and the man cried out that he had touched it. The tiger arrived while it still trembled from the blow, and being deceived, went away angry to live in the jungle.

After this the man sent the cat to ask the tiger, when he killed a deer, to leave him a leg on the village wall, in virtue of their brotherhood. The cat got the message wrong and told the tiger to leave all

¹ Reprinted by permission from the Journal of the Royal Anthropological Institute of Great Britain and Ireland, January to June, 1920.

the deer he killed, which started hostility between the man and the tiger. This story is found in a more or less identical form among the Angami, Sema, Lhota, and Rengma Naga tribes, the Sema making the tiger search for the corpse of his dead mother to eat it.

Man and the tiger are, however, still regarded as brothers, and if an Angami kills a tiger he says, "The gods have killed a tiger in the jungle," and never "I have killed a tiger," while the priest of the village proclaims a day of abstention from work "on account of the death of an elder brother."

After killing a tiger or leopard the Angami wedges the mouth open with a stick and puts the head into running water, so that if the animal tries to tell the spirits the name of the man who killed him all that can be heard is an inarticulate gurgling in the water. The Sema puts a stone as well as a wedge into the mouth to prevent the tiger lying in wait for him after death and devouring him on their way to the abode of the dead, while he also becomes entitled to wear a collar of boar's tusks, the insignia of a successful warrior, as though he had killed a man.

In some tribes whole clans are associated with the tiger; thus among the Changs the whole Hagiya Sept of the Chongpu clan is in some vague way intimately connected with tigers (not in this case with leopards) and is apparently of lycanthropic tendencies. At the same time it is taboo for all true Changs to touch tigers at all, far more to combine, as men of other tribes do, to hunt them. If a Chang meet a tiger in the jungle, he will warn it to get out of the way before throwing a spear or shooting at it. Should he kill one, he is under a taboo for thirty days, and treats the head in the same way as an Angami, putting it with its mouth wedged open under falling water.

The Chang will eat leopard flesh, but not, of course, that of the tiger. The Sema will eat neither, the Angami both—but it must be cooked outside the house.

When it comes to the practice of lycanthropy, we find that the Angami Nagas, though believing that the practice exists and can be acquired, do not indulge in it themselves. Like other tribes, they believe in a village far to the east peopled solely by lycanthropists, a belief which is, perhaps, based on the claims of some clan like the Chongpu-Hagiya of the Changs, in which all members of the community are believed to possess this faculty of taking tiger or other forms in a greater or less degree. But the Angami also believe in the existence of a spring, by some said to be of blood or of reddish-colored water, from which whoso drinks becomes a lycanthropist. They believe that the people of the neighborhood know and shun this spring, but that the danger to strangers is great. Moreover,

when the children of that neighborhood are peevish it is customary, they say, to dip a blade of thatching-grass into the spring and give it to the child to suck. It stops his wailings, but he grows up a were-tiger. The Angami, however, does not practice lycanthropy himself, and the only Angami villages in which persons who do practice it are found are those on the borders of the Sema country, where a large part of the population is Sema by origin. The Sema is an inveterate lycanthropist, and it is in that tribe that specific examples are the easiest to come by.

Both the Angami and Sema agree in holding that there is no actual transformation of the body of the lycanthropist into a leopard. What he seems to do is to project his soul into a particular animal, with which his human body also thus becomes very intimately associated. A leopard which is thus the recipient (from time to time) of a human soul may be recognized by having five claws on each foot, and is called by the Angami *mari* (which might mean "real man") and by the Semas *angshu amiki*, an expression to which I will refer again. I have myself seen a leopard with dew-claws (making five instead of the usual four) killed in a Rengma village, and at once asserted to be the recipient of a lycanthropist's projected soul. Incidentally I have seen and followed in the soft bed of the Dayang River the tracks of a freak tiger which had apparently five toes on its forefeet.

The lycanthropic spring, in which the Angami believe, is sometimes said to be situated in the Sema country, but the Semas give an entirely different account of the way in which they acquire the lycanthropic habit.

The theory and symptoms are clear and recognizable, and differ perhaps from most lycanthropists in other parts of the world. The Sema undergoes no physical transformation whatever. The "possession," if we may term it so, is not ordinarily induced by any external aid, but comes on at the bidding of spirits which may not be gainsaid, and under whose influence the man possessed entirely loses his own volition in the matter. The faculty can, however, be acquired by very close and intimate association with some lycanthropist, sleeping in the same bed with him, eating from the same dish with him, and never leaving his side for a considerable period—two months is said to be the shortest time in which the faculty can be acquired in this way. It can also be acquired, according to some, by being fed by a lycanthropist with chicken-flesh and ginger, which is given in successive collections of six, five, and three pieces of each together on crossed pieces of plantain leaf. It is dangerous, too, to eat food or drink that a lycanthropist has left unfinished, as the habit may thus be unwittingly acquired. The animal whose body

the lycanthropist makes use of, though sometimes the tiger proper (*abolangshu*), is usually a leopard and is known as *angshu amiki*, a word which is said to be derived from the verb *kemiki*, meaning to wander alone in the jungle for days together, since men who do this are most liable to the possession. It may be observed, however, that the root *miki*- also means "to bite."² Cowardly and worthless men, if they acquire the habit, make use of the body of a red cat (*angshu akinu*, probably=*Felis aurata*, the golden cat). The habit is very far from desired. No one wants to be possessed by the habit, and it is, on the contrary, feared as a source of danger and a great weariness to the flesh.

The soul usually enters into the leopard during sleep and returns to the human body with daylight, but it may remain in the leopard for several days at a time, in which case the human body, though conscious, is lethargic. It (i. e., the human body) goes to the fields and follows the usual routine of life, but is not able to communicate intelligibly, or at any rate intelligently, with other persons until the possession expires for the time being. The soul, however, is more or less conscious of its experiences in leopard form and can to some extent remember and relate them when it has returned to its human consciousness. During sleep the soul is the leopard with its full faculties, but when the human body is wide awake the soul is only semiconsciously, if at all, aware of its doings as a leopard, unless under the influence of some violent emotion experienced by the leopard.

The possession is accompanied by very severe pains and swellings in the knees, elbows, and small of the back in the human body, both during and consequent on the possession. These pains are said to be such as would result from far and continuous marching or from remaining long periods in an unaccustomed position. During sleep at the time of possession the limbs move convulsively, as the legs of a dog move when it is dreaming. A were-leopard of the Tizu Valley, in a paroxysm at such a time, bit one of his wife's breasts off. When the leopard is being hunted by men, the human body behaves like a lunatic, leaping and throwing itself about in its efforts to escape. Under these circumstances the relatives of the were-leopard feed him up with ginger as fast as possible in order to make him more active, so that the leopard-body, on which his life depends, may have the agility to escape its pursuers.

Were-leopards are particularly liable to possession between the expiry of the old and the rising of the new moon. Those possessed are liable to a special sort of disease which is believed to attack tigers and leopards generally, but no human beings except were-leopards.

² Incidentally, it also means "to tell lies."

When the leopard is wounded corresponding wounds appear upon the human body of the were-leopard, usually in the form of boils, and when the leopard is killed the human body dies also. It is, however, possible apparently for the soul to throw off the possession permanently as old age is approached. The father of Inato, chief of Lumitsami, got rid of the habit by touching the flesh of a leopard. The village had killed one and he carried home the head. After that, he explained, he could no longer associate with the leopard kind. It is generally held, and doubtless not without some substratum of truth, that a man under the influence of the possession can be quieted by feeding him with chicken dung. Probably this produces nausea.

Possession is not confined to men. Women also become were-leopards and are far more destructive as such than men are. Of men, those who have taken heads are most dangerous, and are believed to kill as many men as leopards or tigers as they have done as warriors.

The actions of the leopard's body and of the human body of the were-leopard are closely associated. As has been noticed, if the human limbs are confined the leopard's freedom of action is restricted, and troublesome were-leopards are said to be sometimes destroyed in this way.

On one occasion the elders of a large Ao village (Ungma) came to me for permission to tie up a certain man in the village, while they hunted a leopard which had been giving a great deal of trouble. The man in question, who was, by the way, a Christian convert, also appeared to protest against the action of the village elders. He said that he was very sorry that he was a were-leopard; he did not want to be one, and it was not his fault. but seeing that he was one, he supposed that his leopard body must kill to eat, and if it did not both the leopard and himself would die. He said that if he were tied up the leopard would certainly be killed and he would die. To tie him up and hunt the leopard was, he said, sheer murder. In the end I gave leave to the elders to tie the man up and hunt the leopard, but told them that *if* the man died as a result of their killing the leopard whoever had speared the leopard would, of course, be tried, and, no doubt, hanged for murder, and the elders committed for abetment of the same. On this the elders unanimously refused to take advantage of my permission to tie up the man. I was sorry for this, though I had foreseen it, as it would have been an interesting experiment.

My information as to were-leopards was obtained directly either from were-leopards themselves or their relatives, friends, and chiefs. Unfortunately I have not so far succeeded in seeing a man actually at the moment of possession. I have had the marks of wounds shown

me by men who claim that they were the result of wounds inflicted on their leopard bodies. Kiyezu of Nikoto, now Chief of Kiyezu-Nagami, who used to be a were-leopard in his youth, can show the marks on the front and the back of his leg above the knee where he had been shot, as a leopard, long ago by a sepoy of the Military Police outpost at Wokha with a Martini rifle. The marks, in corresponding positions on the front and back of the thigh, looked like marks caused by bad boils. Zukiya, of Kolhopu village, showed me fairly fresh marks about his waist which he said were two months old, and caused by shot which had hit his leopard body, and the marks looked as though they might have been caused by shot. Ghowki, the Chief of Zukiya's village, said that Zukiya was in the habit of pointing out the remains of pigs and dogs killed by him in leopard form, so that their owners might gather up what remained. He said that he had a quarrel with his own brother, one of whose pigs he had killed and eaten by accident. Ghokwi mentioned the names of various people whose animals Zukiya had killed and eaten.³ Sakhuto, Chief of Khuivi, showed a wound in his back which was quite new on March 1st, 1913, which he said was the result of some one having shot at him when he was in leopard form a few days before. The wound in the human body does not, under such circumstances, appear at once. It affects the same place in the human body as the original wound did the leopard, but takes several days to appear.

In March, 1919, an Angami interpreter, Resopu of Cheswezuma, at that time working with me in camp, wounded a large tiger near Melomi. Three or four days later the Head Interpreter of the Deputy Commissioner's staff, a very well-known, highly intelligent, and reliable man, Nihu of Kohima, happened to meet a sick Sema road *muharrir*, Saiyi of Zumethi, being carried home. The man, who was employed near Melomi, complained of having had an accident, but on being pressed several times for details, admitted that he had no external injury that could be seen, but was suffering from the effects of the wounds inflicted by Resopu on his tiger form, having very severe pains in his neck or shoulder and abdomen and being haunted by the horrid smell of rotting flesh.⁴

³ According to some a were-leopard who kills cattle may be found in the morning to have bits of their flesh sticking to his teeth.

⁴ In May I went on 10 months' leave. On my return I learned that this man Saiyi had died, during my absence, in Kohima as a result, I was told, of the putrefaction of his internal injuries. Mr. J. P. Hills and myself went into the matter of Saiyi's death. It appears that he was admitted to the Kohima hospital, and that his case was diagnosed by the doctor in charge (Sub-Assistant Surgeon Haralu, himself a Kacha Naga) as tuberculosis of the lungs, the patient also having a tumor near the top of the right hip. Saiyi insisted that Resopu's bullet was inside him, and was so angry at being treated for something else that he quarrelled with the doctor, left the hospital, and shortly afterwards died in his own house.

I have known personally a large number of Semas who are, or claim to be, were-leopards or were-tigers. The Headman of Chipoketami is one; Chekiye, chief of Aichi-Sagami, is another; Inaho, chief of Melahomi, a man of great physical strength and endurance, is perhaps the most notorious. Gwovishe of Tsukohōmi and his daughter Sukheli were only known to me by repute. Gwovishe's son, Chekiye of Lukammi, more intimately. Kusheli of Litsammi, a second woman were-leopard, has her home inside the frontier, and has a most unenviable reputation. The Sakhuto above mentioned died on July 19, 1916, as a result of the leopard which was occupied by his projected soul⁶ having been shot by Sakhalu of Sakhalu on June 30 of that year. It was reported to the writer on July 4 that Sakhalu had shot a were-leopard, but it was then believed to be identical with one Khozhumo of Kukishe, and it was expected that he would die when the news reached him, as the death of the man concerned does not actually take place till he hears that his leopard body has been killed. It was, however, Sakhuto who claimed the leopard and who had the honor of dying to prove his claim. The son of Yemithi of Lizotomi, whose leopard-cat body was killed at Sagami, heard the news as he was returning to his village and expired on the spot for no other reason—a curious example of the power of the Sema mind over the Sema body.

Both Inato of Lumitsami and Inaho of Melahomi related to me independently how, when they were going up together from Pusumi to Lotesami, Inato managed to persuade Inaho to show his tiger form. The latter lingered for a moment behind, and suddenly a huge tiger jumped out on the path in front on Inato with a roar and an angry waving of his tail. In a flash Inato had raised his gun, but the tiger-Inaho jumped in time to avoid the shot, and disappeared. Since this Inaho has had an excellent excuse for refusing to show his tiger form to anyone at all.

It is also told of Kusheli of Litsammi that she cured her husband of making sceptical and impertinent references to her lycanthropic peregrinations by appearing before him in leopard form. His name is Yemunga and he was returning from a business deal in Chatongbung when suddenly he saw a leopard blocking his path. Guessing it was his wife, he laughed at it and told it to go away. It went on and blocked the path a little further ahead. This time he threatened to spear it, and it slid off into the jungle, only to reappear behind him unexpectedly with a sudden growl. This frightened him, and he ran home as fast as he could, the leopard pursuing till near the village, where it disappeared. When he entered his house his wife

⁶ The Sema word is *qghongu*, which primarily = "shadow," but is used normally in Sema eschatology for the soul of a dead person

at once started to mock him, asking why he was perspiring so and whether he had seen a leopard.⁶

The Sema were-tiger, or reputed were-tiger, with whom I was best acquainted was Chekiye, chief of Lukammi and a son of the famous Chief Gwovishe of Tsükohōmi. He would never admit to me that he was a lycanthropist, but none of his Sema acquaintances ever doubted but that his reputation was well deserved.⁷ He came nearest to admitting to me that he was a were-tiger on the occasion of a tiger hunt in which I took part at Mokokechung on March 29, 1916. Ungma village ringed some tigers—there were certainly two full-grown animals and two three-quarter grown cubs present. The old tiger himself broke out early in the beat, mauling a man on his way; shortly after which Chekiye turned up, armed with a spear, but no shield. The tigress broke near him and came within a few feet of him, bit and mauled his next-door neighbour and went in again. Chekiye, when remonstrated with for having stood quietly by and not having speared the animal, said: "I did not like to spear her as I thought she was probably a friend of mine." After the beat he stated that the tigress killed was a woman of Murromi, a trans-frontier village in unexplored country where all the population are said to be were-tigers. He also explained that the tiger in a beat was really far more frightened than even the hunters themselves, which is probably true enough, and shrewdly observed that the use of the tail, which is stiffened up and out behind and swayed at the end from side to side, is to make the grass wave *behind* the moving tiger, so that the position of the tiger's body is mistaken and the aim disturbed accordingly, an observation which seems to be at least true of the result of the waving tail. It was reported that he claimed in private to be identical with the tiger that first escaped, but he would not admit this to me, and there was indeed another

⁶ In February, 1921, the following case occurred: An acquaintance of mine named Zhetoi, a son of the chief of Sheyebu village, became a were-leopard, and ate a number of animals of his own village and of the neighboring village of Sakhalu, including two dogs belonging to the very influential chief Sakhalu himself. In one case in his own village he told the owner of a mithan calf that he would find the uneaten part of his calf stuck high in the fork of a tree in a certain place, which proved absolutely correct. Sakhalu village one day succeeded in rounding up the leopard that had been raiding the village stock, but an urgent messenger came running from Sheyepu imploring Sakhalu to let the leopard they had ringed go, as if they killed it, Zhetoi would die. After this Sakhalu late one evening shot at a leopard behind his granary in the dusk. Very early next morning a message came from Sheyepu to say that Zhetoi had been shot at the night before by Sakhalu and would be kindly forbear.

I had this account independently from two sources, one of which came from Sheyepu, while the other was Sakhalu himself, who told me that he would certainly shoot the leopard, if he could, next time. He has not yet succeeded, and Zhetoi's elder brother told me this year (1922) that he attempted to shoot at a leopard which he happened to meet with when out after deer, but that his hand and fingers became miraculously numb, so that he could not draw the trigger. Of course it proved on inquiry that the leopard at which he had been unable to fire was none other than his own brother Zhetoi.

⁷ He was, however, once caught out in a pure and demonstrable romance by one of my Sema interpreters.

and more likely candidate to this rather doubtful honor. This was an Ao named Imtong-lippa of Changki. While this beat was going on three miles away, he was behaving like a lunatic in the house of one of the hospital servants at Mokokchung. During his possession he identified himself with one of the tigers being hunted and stated that one of them was wounded and speared; that he himself was hit with a stick (the Ao method of beating entailed the throwing of sticks and stones and abuse incessantly to make the tiger come out). He laid a rolled mat to represent a fence and six times leapt across it. He ate ginger and drank a whole bamboo "chung" (about a bucketful) of water, after which he said that he had escaped with two other tigers after crossing a stream, and was hiding in a hole, but that one tigress, a trans-frontier woman, had been speared in the side (in point of fact she was speared in the neck) and had been left behind and would die. (We shot the tigress in the end.) He said there were four tigers surrounded. Chckiye said six. Four actually were seen, however, two grown and two half- or three-quarters grown. There *may* have been others, but it is not very likely. Some sixteen cattle had been killed in two days. This account I took down after returning from the beat, on the same day, from an eyewitness of Imtong-lippa's exhibition, which was seen and watched by a large number of men both reliable and otherwise in their accounts of it.

I have given these details as they show clearly the Naga beliefs on the subject. Of course among the Semas the idea of what one might describe as the projectability of the soul is very pronounced. It is a common thing for a sick person to ascribe his sickness to the absence of his soul from his body, and under such circumstances he takes food and drink and goes to the field or any other places where he thinks his soul has got left behind and summons it, calling it, of course, by his own name. When it has arrived he comes slowly home, bringing his soul behind him. A case once came up before me for adjudication in which an old man named Nikiye, who had been ill for some time, went to the fields to call his soul. It came, and he was climbing slowly back to the village occasionally calling "Nikiye, Nikiye!" over his shoulder to make sure that the truant soul was following. Unfortunately a personal enemy had observed him, and lay in wait in the bush by the path with a thick stick. As the old man tottered by he sprang from his ambush with a yell, and brought down his stick with a thud on the path immediately behind Nikiye's heels. The frightened soul fled incontinently, and the old fellow himself died of the loss of it two days later. To avoid losing the soul a Sema, who makes a temporary shelter away from home,

always burns it on leaving it, lest his soul, having taken a fancy to it, should stray back there by itself.

To return to lycanthropy in particular, the practice described, as distinct from the belief, seems particularly associated in Assam with the immigration from the northwest—that is, from the direction of Nepal and Thibet. The Changs probably have an admixture of Singpho blood, and the Singphos are known to have come from that direction; so, too, the Kacharis who, like the Changs, have a clan of tiger men, and call it the *Mosa-aroi*, and the Meches who have a corresponding clan called *Masha-aroi*, which also goes into mourning for the death of a tiger—both came from the north of the Brahmaputra. Among the Garos also the practice is found, and they too came from the same direction. On the other hand the Khasis, who seem to belong to a different stock—perhaps to the Kol-Mon-Annam race, and to have come from the east—say they believe in the existence of tiger men, but appear to have absorbed the idea from the Garos, who are their neighbors, and not to have possessed it as an indigenous idea, nor to indulge in, or believe that they indulge in, the practice themselves. The Angami, who also does not practise lycanthropy, again seem to have immigrated into the Naga Hills from the southeast and to be intimately connected with the Bontoc Igorot of Luzon in the Philippines. In other ways, however, particularly in language, the Sema is connected with the Angami, though on the other hand there are points of culture which keep suggesting a connection between the Sema and the Garo. One of them is the use of Y-shaped posts to celebrate feasts given to the village, similar wooden posts being used by the Garo, though he is at present entirely isolated from the Sema, while the Kachari ruins at Dimapur contain the same bifurcated monuments in stone. Perhaps the explanation is that the present Sema tribe is the result of the amalgamation of a small Angami element which has imposed itself upon another stock, a process which the Sema tribe itself is still carrying on with regard to its neighbors to the east at a very rapid rate, a Sema chief or adventurer grafting himself and a few followers on to a Sangtam or Yachungr village; this in a generation or less becomes entirely Sema in language and polity, though no doubt retaining its former beliefs and certainly retaining much of its former ceremonial.

The theory that this form of lycanthropy comes from a northern source is perhaps supported by the fact that the form which the belief takes in Burma and Malay, as well as in the plains of India, seems to turn on an actual metamorphosis of the body. Mr. Grant-Brown, writing in the Royal Anthropological Institute's Journal in 1911 about the Tamans, a tribe of Chinese origin in the Upper Chind-

win Valley, notes that they transform themselves into tigers by making water and then rolling naked on the earth they have wetted.

A nearer approach to the Naga belief appears to exist in Malay, but here again actual metamorphosis seems to be essential to that form of lycanthropy. Mr. O'May, writing in *Folklore* in 1910 (Vol. XXI, p. 371) says that in Burma and Sumatra a quite ordinary man may turn into a tiger in the evening without any fuss, and he goes on to describe a Malay game of turning into a civet cat, in which a boy is actually hypnotized and caused to behave like a civet cat, becoming (as the Naga were-leopard does) much exhausted when the trance is over. So, too, Skeat mentions the case of one Haji 'Abdallah caught naked in a tiger trap in Korinchi State in Sumatra (*Malay Magic*, p. 160-163), while Messrs Skeat and Blagden note that the were-tigers of the Malay Peninsula (most unlike the Nagas, here) can not be shot in their metamorphosed condition (*Pagan Races of the Malay Peninsula*, p. 227).

Skeat also records the inverse of the Naga case, in the process by which a possession of the human body by a tiger spirit is invoked to cast out another and less powerful possessing spirit (*Malay Magic*, p. 436), and similarly (p. 455) the induction of a monkey spirit into a girl who, while thus possessed, is capable of the most remarkable climbing feats.

In all these cases, however, the practice differs from that of the Nagas in that either metamorphosis takes place, or it is the animal spirit which possesses the human body, not the other way round. For with the Naga were-leopard the soul is merely projected into the body of the animal, while no metamorphosis of the human body takes place nor is any sort of hypnotism employed—unless, indeed, it be self-hypnotism, and involuntary at that.

Sir James Frazer (*G. B.*, Vol. XI, p. 196) gives instances from Asia of the location of the external soul in animals for the purposes of ensuring its safety or for enhancing the power of the magician. Neither of these two motives appears to influence the Naga were-wolf in any way. It is recognized on all hands that the practice is a dangerous one, and it is said to be rapidly decreasing owing to the increased number of guns in the district, which make it still more dangerous than it was. Lycanthropy is not practiced by wizards, as were-tigers are, as far as I know, invariably ordinary men who do not claim to supernatural powers of any sort. The nearest parallels seem to come from Africa, and Sir James Frazer mentions several beliefs from Nigeria which resemble the Naga belief pretty closely. One other point may be added. In some cases lycanthropy among Nagas seems to be hereditary, or perhaps rather one should say that a tendency towards it may be inherited, as in

the case of many diseases; and indeed Mr. Baring-Gould⁸ described lycanthropy as a disease, associating it in this respect with the mania for cattle-maiming and with a morbid desire to devour human corpses. Cases of both of these I have met with in the Naga Hills, the latter, however, being regarded by the Nagas themselves as symptomatic of extreme insanity; whereas the former is, like lycanthropy, merely a vice which is liable to be very troublesome to the neighbors of those that practice it.⁹

Note on Ao Naga belief as to a certain form of relationship between men and leopards.—One Longrizibba of Youngimsen village was haunted by a leopard which very frequently came at night and slept outside his house close to that place by the wall nearest which Longrizibba himself was sleeping inside. Whenever the leopard came, Longrizibba fell into a deep sleep and could not be aroused by his wife, even though he had previously sharpened his spear with a view to killing the animal. Then he took to sleeping on the platform at the back of his house, when the leopard took to sleeping underneath. On one occasion water was poured on to it, but without discouraging it.

After this and other efforts to get rid of it, Longrizibba induced the leopard to leave him alone by the sacrifice of a dog. This took place in 1919 when I was on leave, and my attention was drawn to the case by Mr. Mills, Sub-divisional Officer of Mokokehung, one of whose interpreters saw the leopard outside the house at night.

Apparently such associations of men with leopards are, according to the Ao tribe, fairly frequent. The relations between the man and the leopard are normally quite friendly and mutually harmless until on an appointed day they are brought to an end by the leopard's devouring the man.

If the haunting is caused by some ceremonial fault on the man's part, it can be ended by a ceremony which includes the surrender of a cloth, a dao sling, and a piece of the man's own hair. If, however, the relationship dates from a man's infancy and has no cause that can be specified, he is unable to break off the relationship.

A mountain with twin peaks is pointed out by Ao as a meeting place of tiger-men.

The practice of surrendering to the leopard a piece of the haunted man's hair is paralleled in the Chang tribe by the practice, when a man loses himself in the forest, of cutting off a little hair and putting it in the fork of a tree for the rock python which is believed to have caused him to lose himself. After this the lost man is able to find his way home. Semas under similar conditions cut a piece off the fringe of their cloth instead of their hair.

⁸ Book of Were-Wolves.

⁹ Prof. Elliot Smith tells me that Egyptian boys practise lycanthropy in association with the forms of the common cat. A bibliography on the subject of lycanthropy will be found at the end of Mr. McLennan's article in the ninth edition of the *Encyclopædia Britannica*, but it relates almost entirely to the European races.

A NEW ERA IN PALESTINE EXPLORATION.

By ELIHU GRANT,
Haverford College.

[With 7 plates.]

Every indication points to the beginning of new opportunities and new interest in the subject of Oriental research in Western Asia and adjacent lands. It is impossible, of course, to forecast the disturbances which may yet arise but the general disposition of the provinces of the old Turkish Empire bids fair to affect favorably the problems of archeology so far as field-work goes. Exploration in Bible lands leads usually to an increase in our knowledge of all the lands and peoples between Persia and Italy. The study of the subject has always been an aid to an understanding of the civilizations which account for more than half of human history. Language, law, philosophy, geography, ethnology, and sociology have often profited by enquiries which were set on foot, in the first instance, for the sake of a better understanding of the Old and New Testaments.

The earlier ages of travel and exploration in Palestine culminated in the excellent publications of Robinson in the middle of the Nineteenth Century. A second period, of the greater excavations, began shortly after that time and now a third seems to have opened under more favorable governmental conditions in the Holy Land.

What heartbreaking difficulties were met in that second, or heroic period! The groaning complaints of those scientific venturers who attempted to explore lands held by the Turks may be read in many a volume and article. Besides the complaints rose the wails of observers who saw the native digger evade the law and bring in his illicit finds from rifled tomb and mound to sell to the curious buyer of "antikies." It still remains true, however, that not a tithe of the ruin heaps of ancient cities and villages have been scratched. The chances are so good that when the opportunity opens, one eagerly scans a dozen possibilities, wondering which place will be most rewarding.

One blessing which followed from the old system of things, or lack of it, was that in spite of the secret digging of the ignorant vender, most of the precious archives in the dirt were spared until

skillful readers of their story could open them. May this benefit continue! From the mounds of Turkestan, Persia, Armenia, Asia Minor, and Syria there is bound to come rich museum material if it can be withdrawn under expert supervision. The shores and islands of the Levant wait in large part for the same skill and conscience quite as much as for funds.

Palestine lies right in the center of this vast field of the ancient orient. It is a little country, about the size and shape of the State of New Hampshire. It is now under British control, administered by a fair-minded representative of the enlightened colonial policy of the Empire, Sir Herbert Samuel. The terms on which qualified explorers may work in Palestine are plain and are construed so as to forward the work. A Service of Antiquities for Palestine has been organized and the antiquities ordinance of 1920 was published in the Official Gazette. An Archeological Advisory Board has been constituted with membership representing British, American, French, Italian, Jewish, and Moslem interests. This board is consulted when there are applications for permission to excavate, for the regulation of any excavations in or about Jerusalem, for the care of any structures of historical significance and for the discussion of such problems of scientific undertakings as have international aspects.

When Jerusalem was entered by the British Army there was found packed in cases a large amount of antiquities which had been gathered during the war. Some of this material seems to have been known of old as museum treasure, while the rest of it is reported as the fruits of recent effort. It is to be placed in a museum in Jerusalem, over 6,000 objects having been catalogued already with that destination in view. Local museums are to be established if possible at other historic places in the land, such as Tiberias, Acre, Askalon, &c.

One keeper of museums is to be in supervisory control of all these local collections. At Jerusalem discoveries of a large sculptural and architectural kind will be housed in the Hippicus Tower of the Citadel.

Harvard University will continue its investigation of ancient Samaria. Chicago University will have the privilege of digging and examining the remains at Megiddo, while to the University of Pennsylvania has been allotted the important site of old Bethshean. The last mentioned institution began work in June, 1921, under the capable charge of Dr. Clarence S. Fisher. It was reported in the autumn of the year that Doctor Fisher had discovered a large stone stela (pillar) with Egyptian hieroglyphic writing numbering more than a score of parallel lines. Inscriptions have ever been one of the most eagerly sought objects of explorers because of the first-hand testimony which they afford to the life and thought of the ancients as well as their high value for philologists. But inscribed

material from Palestine has been very scarce. Thousands of objects of every other meaning have been found, with only a few notable written records so far, but we are likely to see an increase in favor of written material from further exploration.

Down at Ain Duk, near Jericho, a Turkish shell dug into the ground and laid bare a portion of a mosaic floor. This has been further excavated, and the building which contained it has been shown to be an old sacred place, perhaps a synagogue. The inscription is in Jewish-Aramaic. It is but nine or ten lines long and is thus translated by S. A. Cook in the *Palestine Exploration Fund Quarterly*:

Honoured be the memory of Benjamin the Manager, son of Josah. Honoured be the memory of everyone who exerts himself and gave or shall give (?) in this holy place, gold or silver, or any valuable . . . in this Holy Place. Amen.

This appeal is the equivalent of a modern exhortation to give generously to the collection.

The excavation made by the French School of Archeology shows the ground plan of a group of buildings clustering near the synagogue. Further inscriptions, Jewish and votive in character, have been revealed and many pictures in mosaic which formed the flooring of the nave of the structure. Daniel is represented in the lion's den, and there is a zodiac with appropriate figures and descriptive writing and a large mingled composition of patterns drawn from vegetable, animal, and fantastic designs. (*P. E. F. Quarterly*, Oct., 1921, pp. 185f and 189.)

An inscription was found on the hill Ophel at Jerusalem just before the war, but was not made public until after the war was over. It probably dates from the first Christian century, in the days of Gamaliel and Paul. It seems to refer to the restoration of a synagogue and hostel for foreign Jewish pilgrims coming to Jerusalem. The Jewish freedman who did this belonged to a family which had been benefactors of the holy place on the same site before. His name was Theodotus and he is called the son of Vettenos, a priest and head of the synagogue and son of one who held the same distinction before him; indeed, Theodotus was the grandson of such a dignitary. Theodotus made building repairs and construction of the synagogue for the purpose of the reading of the law and its teaching and further provided rooms and plumbing arrangements for the entertainment of foreign Jewish pilgrims.

Dr. Nahum Slousch has found an ancient synagogue near Tiberias, thought to be the Kenista d'Hammata mentioned in the Talmud. A seven-branched candlestick made of marble, besides mosaics and inscriptions, has been found at the site.

The Palestine Exploration Fund (London) began actual digging at Askalon in September, 1920, under the superintendence of Dr. John Garstang. Camp was pitched at a spot among the ruins where Roman masonry is to be seen and a systematic collection of all fragments on or near the surface was made at once. The high commissioner came down from Jerusalem and cut the first sod on September 10. Askalon has been in mind as a site for work for many years. In 1911 Dr. Duncan Mackenzie made a visit to the ruins which he described in the *Quarterly* for January, 1913 (p. 20ff), with a plan of Askalon, by Newton, accompanying the article. The city is on the Mediterranean coast, 15 miles north of Gaza and 30 miles south of Jaffa. It had a busy history from the time of Ikhnaton (Amenhotep IV) of Egypt, about 1370 B. C., until 1270 A. D., when Saladin's was the mighty name in those parts. In the Tell el Amarna collection of letters found in Egypt there is one from Yitia of Askalon, whose scribe wrote for him in the fashionable cuneiform of the day. Yitia professes utmost loyalty to his suzerain, says that he is sending tribute to Egypt, and is standing firm as a staunch supporter of the Pharaoh in Palestine. Meanwhile the King of Jerusalem accused the King of Askalon of treachery to Egypt in aiding the hostile Khabiru. The city of Askalon was rebellious and had to be subdued by the Pharaohs Rameses II and Merneptah, who mention it in their inscriptions. The Peoples of the Sea, who may be the stock from which the Philistines sprang, overran the place, and near that period it begins to be a Philistine stronghold hostile to the Hebrews and, later, to the Jews. It figures in the story of Samson (Judges, 14:19) and "Tell it not in the streets of Askalon" wails forth in the Song of the Bow (II Samuel, 1:20). Sennacherib (703 B. C.) mastered it and it is mentioned on the Taylor Prism. The Scythians reached it in their sweeping raids (630 B. C.). Askalon was always a nest of anti-Semitism. Herod the Great was born there, which fact was hurled at him in the taunt that he was a Philistine. He was generous in his building program for Askalon. Lately the excavators have turned up Herod's statue in gigantic size. Through Christian, Arab, and Crusading times the city held important place. A Christian bishop had his seat there.

The nearest remains to the exploring party as they squatted on the site would naturally be the youngest, those left on the oft occupied ground by Crusaders, Byzantines, and Arabs. A Crusaders' church has been identified. A Byzantine church of the seventh century shows remains of one apse and three high but roofless walls. Among the few inscriptions found is "an honorific decree in favor of one of Titus' centurions" who, curiously enough, has been identified with the centurion whose name, with companions, had been scratched on the foot of one of the colossi at Thebes, two years

before his mention at Askalon, commemorating the fact that at a certain morning hour in April, 65 A. D., the group had heard Memnon salute the Dawn. (Hogarth, as reported in *P. E. F. Q.*, July, 1921, p. 132.)

The humblest and yet the surest aid to the historian so far has been the study of the domestic pottery scattered over and through the heap. Experience has taught explorers in Palestine that each successive layer in a mound, representing a corresponding period of life in the olden days, is best labelled by its most common brand of clay pottery fragments. From the earliest population of a site to its latest inhabitants, the quantity of rare, strange types of vases, cups, jars, bowls, etc., used by housewives will be vastly outweighed by a characteristic type of clay vessel most in vogue at any given cultural period. Due to this fact it has been found possible to make a ladder scale of pottery types from earliest times to the latest occupation. Askalon has shown in unusual completeness the possibilities of such a pottery scale, which stands as a test of the various layers of relics turned up, whether these be walls, art objects, or implements. Mr. Phythian-Adams has gone most carefully into the question of the stratification of the *débris* at Askalon. Six trial sections were cut into the old city. One of the sections proved to be what was sought, an undisturbed succession of occupational strata. This cutting ran through 10 meters of *débris* and affords a table of contents, more or less, of 2,500 years of Askalon. The excavator has been able to put his finger on the layer in the pile which actually belongs to the Philistines. This measures about 2 meters and indicates successive Philistine occupations, the variation of which from each other is illustrated by finding the remains of a house, latterly of brick, but standing on foundations of stone.

Most of the surface at Askalon has been plotted in numbered fields in anticipation of systematic excavation. There are nearly 200 of these. In field 61 a statue of Fortune lay already exposed and another statue, of Victory, was soon uncovered. The ruins of a large marble building after the Corinthian order were cleared, and another statue, called tentatively "Peace", holding a palm branch, along with the lower half of a life-sized Apollo, came to view.

The work, interrupted through the winter months, was resumed early in April, 1921. Fifteen expert Egyptians and about 130 common workers were employed. In field 61 the so-called Tycheion, or Temple of Fortune, was excavated. It had been progressively enlarged until it had a breadth of 30 meters. An interesting theater abuts on it in the area numbered 67. Beyond this have been found the lines of a *temenos*. The foundations of the large building reach down to the Philistine level. The peristyle alone has a length of 77 meters, besides the portico and an apse running southwards. At

the northern end stood formerly the portico, three or four columns deep. Columns $8\frac{1}{2}$ meters high are reported. Fortunately those who in the past dug out and carried away the ashlar for building purposes left, as useless for their need, many architectural fragments which, constantly turning up, help in the determination of questions of style and execution. This same quarrying in ancient and modern times for building materials has tossed about much of the wreckage, so that much confusion has resulted, and would be utterly discouraging if it were not for the stratification studies mentioned above. The reports of Garstang indicate a thoroughgoing clearance of the great building, the complete analysis of which has not been published as yet. The building stood near the junction of the main roads, and must have been of first-rate importance through several periods of history. The foundations go down into the Philistine level, though what that may signify has not been made clear.

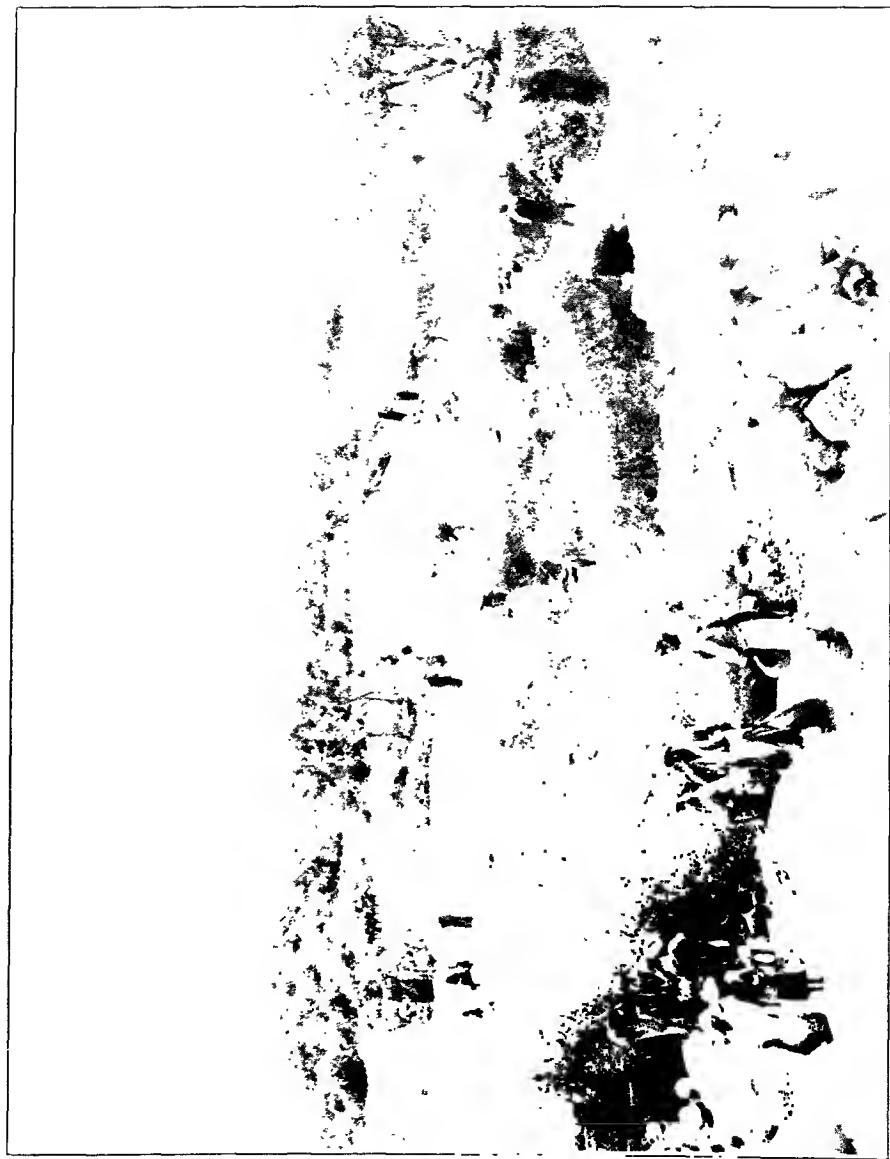
The work on this structure in 1920 had disclosed at the southern end a tank which the explorer was inclined to identify with the famous Peace Pool mentioned by Antoninus Martyr (560-570 A. D.). Twelve to sixteen feet below the tank were found the retaining walls of a similar structure. Fancy was naturally caught by a potsherd, found in situ, on which was a decoration showing a man fishing with a rod and line on which were hanging two fish. This suggested the old pool and sanctuary of the goddess Derketo, half human and half fish. The tank is at the center of three concentric circles, arcs of which were formed by semicircular walls lying to the south of the tank. These were the boundaries of terraces or benches, each successively higher than the tank and paved as ambulatories, which were lined with Carrara marble. In the southwest corner of the great structure Garstang identified materials running through a thousand years' use of the building, Hellenistic, Roman, and Byzantine. It was here that the inscription honoring the officer in Titus' Tenth Legion was found. A date in the second or third century A. D. is allowed to a Greek lintel inscription found here which reads "Prosper Askalon, prosper Rome."

Perhaps the leading hope in the present excavations is that problems relating to the Philistines may be illuminated. Decorated wares from the Philistine and pre-Philistine periods have been identified, and as the stratum just preceding the Philistine and the one immediately following it have been located it is possible that a part of the expectations may have fulfillment. Several layers below the Philistine remains show communications of the inhabitants with the Mediterranean lands, and date about the time of the eighteenth and nineteenth dynasties of Egypt. Still lower down were found caves containing artificial objects. The oldest objects recovered have been recognized as of the period of the Hyksos. The site yields hundreds

of pottery types. The Cypriote "wishbone" handle is there, belonging to a bowl showing the ladder design with a brown decoration on whitish-gray. "Ægean painted ware," "base-ring ware," and other pottery from the Mediterranean and early Palestine are represented.

By one of those curious twists or prejudices in historical usage the word "Philistine" has come to mean "uncultured," though in their own day the people named may have stood for the best in the civilization of Canaan. So far as now known, they seem to have been descendants of the Sea-raiders whom the Egyptians repulsed by land and sea, scattering the remnants in Syria and Palestine. This strain of westerners, Europeans of a sort, from the islands and northern coasts of the Mediterranean, coming to the coasts of Syria-Palestine possessed the skill of the sea and founded colonies on the shore which never lost touch with the Cretan or Ægean pursuit of seafaring. In the south, however, such folk would be driven inland more surely, because of the inhospitable shore. In Palestine they lived in a kind of Hanseatic League of trading cities in the sea plain. Askalon was one of the few Palestine cities possessing a semblance of a harbor. The line of Philistine cities extended from Beth Shean, where Doctor Fisher is excavating, through the plain Esdraelon and the maritime plain nearly to Egypt.

The French, to whom Syria now pertains by mandate, have begun work in Phenicia near Tyre. Work was undertaken at Tell Mashuk. The site of ancient Dan will be available to American archeologists as soon as they can procure the means to excavate there. To this has been added as an American opportunity the site of old Dothan. Capernaum has been undertaken by Pere Orfali. Thus it will be seen that a systematic approach to the problems of history in Palestine is under way, and none too soon, for projects of irrigation, engineering, and modern improvement bid fair to disturb the records of the soil before they can be properly interpreted. Plans for draining Lake Huleh, the construction of reservoirs for irrigation, light, and heating plants south of Galilee are already planned. Human culture from the Stone Age to the time of the Crusades lies in the palimpsest record of this wonderful land, which is in itself a museum of human yearning and achievement.



EXPLORING ASKALON IN 1921. (FIELD 61.)

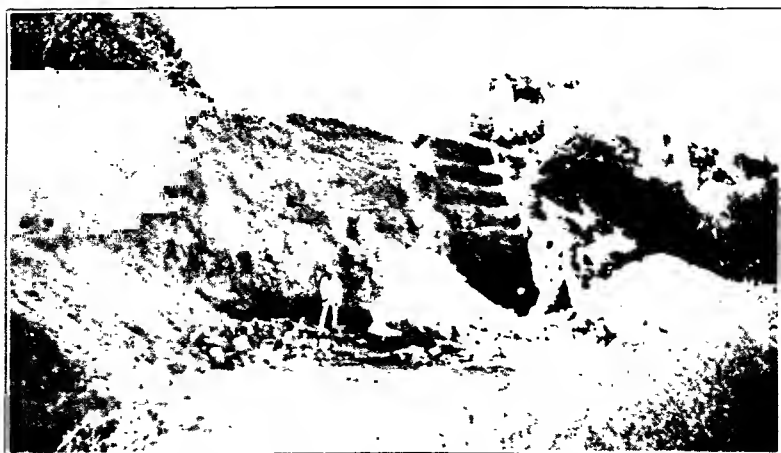
Courtesy of the Palestine Exploration Fund, London, which is doing the work of excavation.



1. THE HIGH COMMISSIONER, SIR HERBERT SAMUEL, CUTTING THE FIRST SOD
IN THE EXPLORATION OF ASKALON.

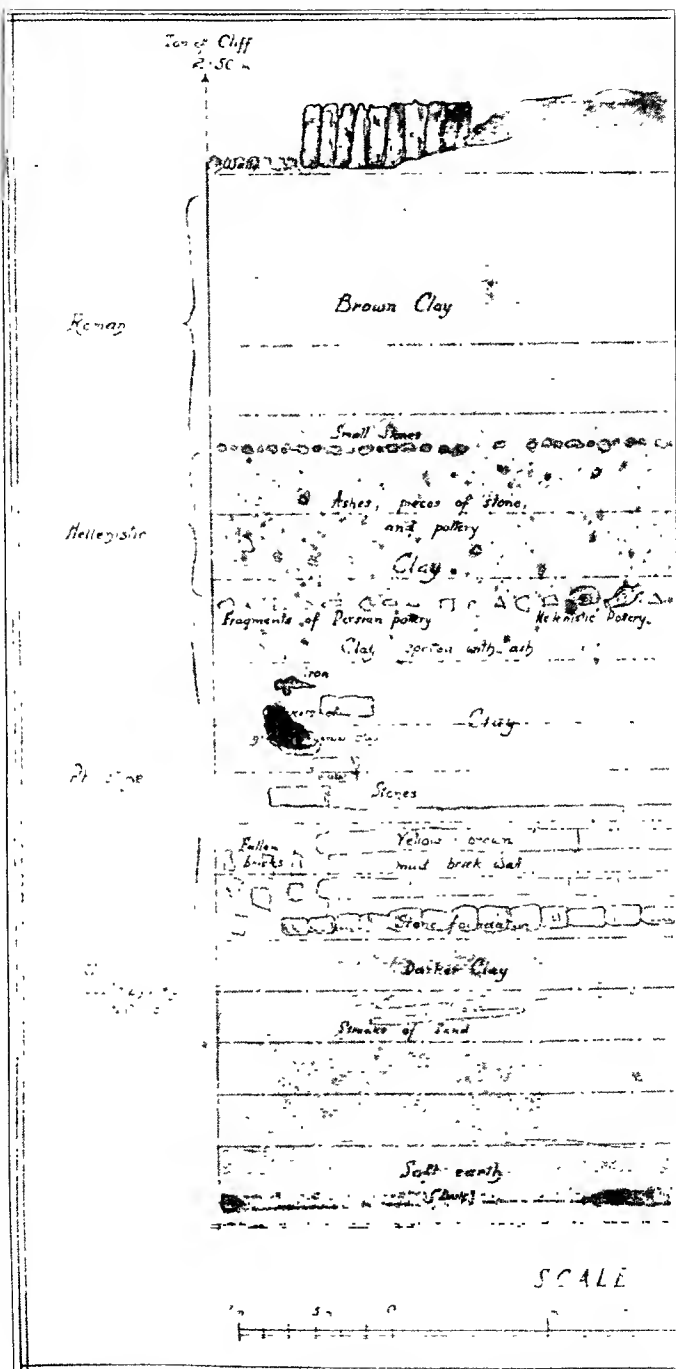


2. ASKALON. FIELD 61 FROM THE SOUTH, GETTING BELOW THE SURFACE.



FIELD 187, NORTHERN CUTTING.

(After the Excavation.)



SHOWING THE DIFFERENT LAYERS OF THE OLD CITY OF ASKALON.



AN ISIS FROM THE TYCHE FIELD AT ASKALON.

Palestine Exploration Fund



1. AN IMPROVED TACKLE FOR BRINGING A PIECE OF STATUARY TO THE SURFACE AT ASKALON.



2. THE PEACE POOL AT ASKALON.

Palestine Exploration Fund



VICTORY UPON THE EARTH.

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THE ALIMENTARY EDUCATION OF CHILDREN.¹

By MARCEL LABBÉ.

Professor of the College of Medicine of Paris, Physician at the Charity Hospital.

A good diet is the first consideration in obtaining good health. Besides providing, one should know how to nourish oneself.

This can be taught. I am not of the opinion of J. J. Rousseau, who states that man left to himself will naturally live right and will never have indigestion. No more do I believe with H. Spencer that a child's appetite is a judicious guide for it. Though hereditary instinct is sufficient for animals, it does not seem that it would be a suitable guide for man, who is, from the point of view of hygiene, the least rational of the animals. An alimentary education is, then, indispensable.

It should be commenced early. It is, in fact, during the growing period that benefit or harm from the diet reacts most strongly on the health. It is during the first years of life that habits are formed, that reflexes are created, which later direct the entire organic life of the individual. It is easy to act on the plastic nervous system of the child in order to instil into it good habits just as it would be difficult to uproot vices to which the adult has become accustomed.

Alimentary education should, then, be addressed above all to children. This idea is not new; the Persians of the heroic ages had already felt the truth of it. We read in Montaigne that the education of the eldest son of the king was entrusted to four teachers, one of whom was the most temperate man of the kingdom.

The Americans of to-day think, in the same way, that in order to accomplish the hygienic education of the people, it is necessary to commence by training the children, who are the men and women of to-morrow, and it is on them that is brought to bear the principal effort in the prevention of tuberculosis and in instruction in alimentary hygiene. For these reasons I will discuss this vital question: The alimentary education of children.

The methods of instruction have been much discussed. Each has extolled his own. With Henri Labbé, I am of the opinion that we

¹ Lecture given at the Sorbonne. Translated by permission from the *Revue Scientifique*, Sept. 10, 1921. (*Translator's Note*.—This article, of course, presents the subject chiefly as it relates to France, though it also has a general application of interest everywhere.)

must not be exclusive and that each system has its advantages. In a report presented to the National Committee on Social Hygiene in 1919, we showed that there is a place for using all the vaunted plans of education, simultaneously or successively, by adapting them to the social station and to the age of individuals. It is evident that we would not use the same methods in dealing with a baby, a young child, and an adult.

In the case of the infant, the nurslings, the bottle fed, or those already weaned, it is the mother who gives them their alimentary education and who teaches them hygienic habits. It is therefore to the mother and to the nurse that the doctor's advice is addressed. This is the affair of the specialist in pediatrics, whether obstetrician, pediatricist, or hygienist, whether infirmity attendants, nurses, or specialized nursemaids. The education is given in the family, at the dispensary, at the infant asylum, or at the day nursery. For the nursling, much has already been done. Establishments such as the Institut de Porchefontaine and the new Institut de Puériculture, organized by the State, render great service by spreading, through precept and practice, correct principles of infant alimentation.

Once past this first period of life, the alimentation of the child is left somewhat to chance. And yet it is not less important. During the first years, whether the child is brought up at home or goes to the kindergarten, its education should be begun. It is either direct or indirect. Direct, if it is addressed to the child itself through practice, through example, through games, through little alimentary lessons, through "health chores"; indirect, if the instruction is addressed to the parents, by means of lectures, sample dietaries, posters, and pamphlets.

Later, during childhood and adolescence, the education of boys and girls should be given in the schools by means of theoretical and practical lessons. It is the girls especially who should be addressed, since they are destined to become the nurses and the housekeepers; besides the rules of alimentation, it is desirable to teach them cooking, domestic economy, and the conduct of the household.

It is important in giving this alimentary instruction not to fall into pedantry and not to try to put the question of nourishment into sterile formulas, intelligible only to scientists. It is above all by practice and by example that we should proceed; theoretical instruction should be only an explanation of the facts.

During the first six or seven years of its life, the child is usually kept in the home with its parents. In ordinary families, it is preferable that the child should not appear at the family table and that it be raised apart, in the nursery. If it sits at the table with the parents, they assume responsibility for its alimentary education—a

heavy responsibility, for it is often upon the habits, good or bad, contracted at this time, that depends the future health.

Consequently, the parents should watch themselves carefully and correct their own faults. They must avoid having meals at irregular hours, eating too long or too rapidly, hasty mastication, too abundant drinking, the abuse of wine, an excess of salt or pepper with which the dishes are seasoned; they must be careful at the table, materially as well as morally.

The child, indeed, sees every motion; it retains them and imitates them. If later on it has bad eating habits, it is most often the parents who are to blame. How many people by their unconscious example, sometimes even by conscious persuasion, teach their children at this time to be large eaters, heavy drinkers, food bolters, and by doing so, make of them later obese people, alcoholics, or dyspeptics. Certain diseases such as obesity are less often due to an inevitable heredity than to a vicious, pathogenic education given by the parents.

For children who go to the kindergarten or to the public school, there is no better means of alimentary education than the school lunch room, provided that it is organized according to the principles laid down by the school physicians.

It was in 1881 that the first school lunch rooms were established. Since then, they have multiplied in the kindergartens and the primary schools of Paris and of the Provinces. Their aim is to provide a warm meal, composed of two or three dishes, which the child eats with the bread, the dessert, and the beverage which it has brought from home.

All the children do not participate, but only those whose parents desire it. The meal is free for those without means, and paid for by those who are able to give the 50 centimes which it costs. The expenses of the school lunch rooms are defrayed in part by the price of the paid-for meals, in part by a grant from the Municipal Council.

This is an excellent undertaking but one whose organization is still imperfect. The medical inspectors of the schools have at different times voiced their criticisms; the lunchrooms exist in only a small number of schools; they function only during the three winter months; the menus are sometimes badly devised, ham, pork, and sausages too often in certain schools replacing fresh meats; finally the lack of space makes it necessary in many schools to serve the meals in the school yard, where the children are exposed to cold and to dust, or, indeed, in the schoolroom itself, where the air is not sufficiently renewed.

It is very important that school lunchrooms be more generally adopted; that there be planned and installed a suitable space for

them, comprising a kitchen, a well aired and well heated dining hall and a wash room. The dining hall should be provided with the necessary equipment so that each child may have his own plate, drinking glass, spoon, knife and fork, and napkin, and so that he may sit comfortably at a table. Absolute cleanliness should reign in the kitchen and the dining hall.

The menus should be suitably chosen with regard to the age of the children and to the tastes prevalent in the country. The Americans, in their school "lunches," have special menus for schools attended by Jews and by Italians. The question of meat in the diet of children has aroused numerous controversies. The partisans of vegetarianism are arrayed opposite those who believe in the usefulness of meat. The conclusion resulting from the discussion among school physicians has been that meat should be given in small quantity two or three times a week in the kindergartens, and every day in amounts of 40 to 60 grams to the pupils of primary schools. Meat might be replaced by eggs. Milk, vegetables, and in a general sense, fresh, natural foods, containing vitamins and substances indispensable for the building up of tissues, should be made a part of the diet. Finally, the children should be allowed sufficient time for eating; they should have half an hour for the noon meal.

Well organized, the school lunch room will have not only a hygienic value but it will fill an educational function—through the choice of foods, through the surveillance of mastication and of drinking, through the washing of the hands before the meal and the habit of eating in a cleanly way, the meal at school will provide instruction in the fundamentals of alimentary hygiene.

It is the school nurse, with which every modern school should be provided, who would be entrusted with the duty of supervision. She would order the menus, look after the cooking of the dishes, distribute them to the children, and preside at the meal; she would also forbid the use of wine or coffee in too great quantity and suppress the brandy which in certain Provinces the parents put in the child's basket.

The medical inspectors of the schools should supervise and criticize the menus, which would be presented to them. In their consultations they would prescribe special menus for weak or sick children (extra diet, supplemental meat, vegetable, or milk diets, etc.).

Thus organized, the school lunch room would be not only a type of economical restaurant but it would become a means of treatment, an example of hygiene, a place of instruction in dietetics. The menus would be an indication which would show the parents what should compose the child's diet.

The school nurse could do even more by giving, in family conferences or in private talks, advice to parents. If her investigation

or the health docket which should be made up for each child entering school shows her that bad dietary practices prevail in the family, that the child is over or under nourished, that it eats irregularly, that it takes too much meat or drinks too much wine, for example, she should explain to the parents the dangers of these faulty practices, and if she finds them interested and without prejudice she would give them valuable points on the subject of general hygiene, the household tasks, and culinary preparation.

The school, with its lunch room, is called upon to render great service to the health of children. But it is not only intended for healthy subjects, or, indeed, for those merely predisposed to sickness. There are children who on account of debility or of illness are prevented from going to school, and who, in order to recover from enteritis, anemia, or scrofula, by which they have been attacked, require regenerative diet and hygienic instruction which their parents do not know and can not give.

To fill this need there is an excellent institution, the nutrition clinic. The Americans have inaugurated it and put it into practice. A woman of high intelligence and great force, Miss Frances Stern, has organized in Paris, in the nineteenth ward, a clinic of this kind. Children from 4 to 7 years old temporarily kept away from kindergarten or from the primary school come to spend the day on the premises of the clinic, the parents bringing them at 9 o'clock in the morning on their way to work. They are kept clean, taken care of, made to play and to rest, in the garden if the weather is good, inside if it is bad, and they are given a luncheon and dinner which are wholesome and strengthening. Under the influence of this good care, the poor little ones gain in appearance and in weight; they return to health. In bringing and calling for their children the mothers learn through example and the advice given them by the trained nurses how to care for them. Consultations on alimentary hygiene held by physicians, assisted by the nurses, culinary demonstrations, distribution of food and of medicine complete the work.

The practical education given by the school lunch rooms and nutrition clinics are worth more than all theoretical instruction. I do not mean, however, that this is useless. There are many ways of instilling ideas of alimentary hygiene into children's minds, and all of them should be used.

When we are dealing with the very young, with kindergarten children, it can not be made a matter of lectures. It is by amusing them that we must instruct them. We know the importance of games in their education when they are properly directed. With cardboard models representing the principal foods, like those used on the stage, with a doll's kitchen like those given to little girls, how many things they can be made to understand regarding the

origin, the nature, and the rôle of alimentary substances; regarding the composition of meals for workers; regarding the danger of certain dishes.

We know how much children like to play sick, or to play nurse and doctor. It should be easy by playing with them to teach them some knowledge of hygiene; one could stimulate in them questions and answers about indigestion, diarrhea, constipation, growth; about the part played by milk, vegetables, gruel made from cereals, etc.

I can readily imagine the conversations of this kind among the improvised mothers and the doctors in short trousers: "Your little boy has diarrhea, madam; you must give him vegetable broth." "Your son vomits, which shows that he has eaten too much, or that he does not chew his food well; you must teach him to chew a piece of meat thirty times." "Your daughter has colic; it is because she has eaten too much candy. You should give it to her only for dessert. Or perhaps she has eaten green fruit; give her only cooked fruits." Or again: "If your child has worms, it is because he eats fruit which has been badly peeled or is poorly washed; because your greens are not properly cleaned; because he does not have his hands washed before coming to the table; or because he puts his soiled fingers in his mouth after having played in the dirt."

We can imagine many other pieces of advice on alimentation to put into the mouths of the children. I am sure that the skilled nurses of the kindergartens would be able to make effective use of play in the education of the little ones.

In dealing with older children, pupils in the primary school who learn lessons and do tasks, it would be possible to introduce information about alimentary hygiene into the problems in arithmetic. The majority of problems of alimentation come under the rule of three; instead of giving in the problem, according to the old custom, the number of spigots which fill a reservoir or trains which meet, there could be used the calculation of the energy needs of a worker, of the alimentary ration of a baby, of the comparative value of foods, of the composition of an economical diet. They would be asked for instance: "Is it more economical to make a lunch equivalent to 250 calories of sugared milk or of bread and chocolate?" The answer would necessitate the child's consulting tables which give the composition of foods, their calorific value, and their price; and after several exercises of this kind the young scholar would retain some knowledge of dietetics and of domestic economy.

The composition of ordinary foods should be known by everyone. To know that milk is a complete food, containing albumen, sugar or lactose, fat or butter, and minerals rich in lime; that the egg is a food for development made of albumen and of fat; that meat fur-

nishes especially albumen; that fruits contain sugar and potatoes starch, is equally useful for the mother who nurses her baby, for the worker who must renew his energy economically, and for the young man who goes in for sports.

But it can not be a question of imparting this information by means of books, by forcing the scholars to learn by heart tables of the composition of foods the way we formerly learned the list of departments or of Greek roots.

It is necessary that they enter the mind without effort, without becoming a bore, almost unconsciously. This is made possible by the colored plates figuring the composition of the ordinary foods published by the Americans: The general form of the food is easily recognized, and the red, blue, yellow, green, and brown colors indicate by their relative depth the proportion of albumen, of carbohydrates, of fat, of water, and of mineral substances which it contains.

If these plates are posted on the wall of a school, the child, in looking at them every day, will easily learn to know the type of fat food, such as butter or oil, which is entirely yellow; the type of carbohydrate food, sugar, which is depicted in blue; the type of food rich in protein, like meat and smoked fish, which is shown in red.

Figures showing the exact percentage composition of the foods make of these plates a real dictionary of alimentary substances. I have placed them on the walls of my consultation room at the hospital, where I use them in dietetic demonstrations. However, as they are of small size and in small type, they are adapted only for small lecture rooms. I have also had designed after these, three large placards, reproducing the types of foods which are the most useful to know, which are for use in larger auditoriums. Placards prepared on this model will render great service in instruction in alimentation in primary or secondary schools, as well as in medical schools.

It is also through the eyes that we can teach children the principal dangers to which unwholesome nourishment exposes them. Towards this end, I have had designed by Mme. G. B. Blanchard four placards, representing the danger in milk, in meat, in water, and of dust and dirt in food.

On the first we see how milk coming from diseased cows or goats, kept in dirty containers and milk houses, exposed to dust, mixed with infected water, can transmit a series of diseases such as tuberculosis, apthous fever, Malta fever, typhoid fever, dysentery, infectious gastroenteritis of children.

On the second, we see meat from animals affected with infectious or parasitic disease, meat badly preserved, becoming the cause of morbid transmission such as tuberculosis, glanders, typhoid fever, tapeworms, etc.

The third shows water coming from sources badly collected, not protected, polluted by men or animals, transmitting typhoid fever, dysentery, or intestinal parasites.

Finally the fourth shows the processes of secondary contamination resulting from bad preservation or dirty handling of foods: For example, the dust of the streets adhering to the fruits, the greens, and the pastries carried in pushcarts and displayed without protection in the store fronts of groceries and fruit shops; the dust of apartments which settles on the surface of dishes which have just been prepared; greens infected by typhoid-polluted water; the tuberculous cook who carelessly coughs over the dishes which she serves; the cook who is a carrier of typhoid germs or dysentery, who by means of her unclean hands transfers them to the food; flies, which having collected dangerous germs from privies, come to leave them on the surface of foods; finally the dog, too welcome visitor in the kitchen, who transmits parasites of which he is a bearer.

The dangers which menace us are too numerous and too diverse to be all represented in a series of four plates. But the principal ones are there, and in a form which the mind can easily grasp.

These plates have the happy privilege of making the children, and even adults, laugh; they hold the attention, they are deciphered like a rebus, they are commented on scientifically, and they impress the story they tell on the memory of all. Would it not be desirable that they be printed in large editions and adopted for school equipment?

These plates are of the type of the posters, pictures, pamphlets, and postal cards published by the American commission for protection against tuberculosis in France. It is believed that they would render equal service if they were reproduced in the form of simple pictures of the Epinal kind, in the form of illustrations for little tracts, or in the form of postal cards to put in the hands of children.

Their form is, moreover, by no means limited, and I can well imagine possible graphic representations of the elementary dangers which menace us, of the mistakes to avoid, and of the precautions to take. The commission for protection against tuberculosis has published amusing pictures showing children the danger of dust and flies, of the necessity of washing the hands before coming to the table, and of brushing the teeth to keep them in good condition. These are some of the precepts of alimentary education: It would be desirable to formulate and to depict a series of others to teach thorough mastication, not to eat too fast, not to drink too much during a meal, not to abuse alcohol, etc. Certain of these pictures would be common to the antialcohol campaign and to alimentary education.

In fact, what is the campaign against alcohol if not one of the chapters of alimentary hygiene?

If this advice, addressed to children, were heeded and followed (and here it concerns measures of personal hygiene which have no part in the police power of the State), how many diseases we would be able to avoid!

The Americans have accomplished some interesting results in this direction. There is a series of nine posters published by Gillett, which show: The type of child made vigorous by means of a proper diet; the comparison of a well nourished with a poorly nourished child and the reasons why the diet of the latter is bad; the comparative nutritive value of coffee and milk, of bouillon, of vegetable soup or milk soup, of vegetables and canned or dried fruit as they are found in large groceries, finally the usual foods; the series of foods which are of value in building up the skeleton; the most economical and the most advantageous way of spending \$5 for food.

These pictures, placed where children can see them, in the lunch rooms, in the dispensaries, and in the schools, will surprise and amuse them; commented on and explained by doctors, nurses, or instructors, they will teach them some important facts of alimentary hygiene.

We can, moreover, imagine others, not less useful in demonstrations. I would propose, for instance, the following series, designed to show the special rôle of various foods in answering the bodily needs: (1) Those which make muscle (meat, eggs, dried vegetables, cheeses, milk); (2) those which make bone (milk, whole cereals); (3) those which aid growth (whole cereal porridge, cereal gruels, whole wheat bread, milk, eggs); (4) those which make fat (bread, meal, cereals, farinaceous vegetables); (5) those which produce bodily heat (bread and butter and preserves, goose grease, cod-liver oil); (6) those which produce energy for climbing, running, or playing games (sugar, sugared fruits, honey, candy, chocolate); (7) that which is necessary to climb on foot to the top of the Eiffel Tower (seven lumps of sugar—sugar is for the human body what coal is for the steam engine; to climb mountains, a stick of chocolate is better than a thick beefsteak); (8) he who would travel far should take in his sack sugar, chocolate, dry biscuits, and some preserved meat.

If the pictures make an impression on the minds of the children, the form of the thought is just as important; mottoes and proverbs, commandments, and succinct formulas are easily retained in their memories. For this reason I have thought it would be interesting to draw up "commandments" of alimentary hygiene, to be posted in schools, dispensaries, and refectories. In the following twelve precepts I have summarized the essentials.

COMMANDMENTS OF ALIMENTARY HYGIENE.

1. Clean hands, clean plates, clean dishes makes the food appetizing and wholesome.
2. Eat at regular hours, chew carefully, rest after meals.
3. Harken to your appetite, but be not its slave; eat what you ought and you will be better for it.
4. Avoid extremes; too much and too little are equally harmful.
5. Meat makes the muscle, but sugar gives it strength.
6. To climb mountains, a cake of chocolate or sugar or an apple is better than a thick beefsteak.
7. A little wine nourishes; much alcohol kills.
8. It is with milk and vegetables, and not with meat, that our skeleton is built up.
9. We must drink water to wash internally just as we wash the skin.
10. Spinach, chicory, cabbage, greens, and fruits do the sweeping out of the intestine.
11. Green vegetables, potatoes, beets, turnips, and fruits alkalize the organism. They are the antidotes for meat and eggs which acidify it.
12. Eat your food well cooked; it acquires flavor, digestibility, and decreases in toxicity.

To help me in this work several of my students have drawn up the commandments which seemed to them the most useful. Each has put into it something of his own mind, imperative, satirical, scientific, or artistic. I publish here one of these trials, that of Mme. Requin, which by its literary form is capable of impressing strongly minds sensible to the charm of poetry or of being retained by the memory of children.¹

1. De l'hygiène si tu suis les prescriptions
Tu pourras du Docteur éviter les potions.
(If you follow the prescriptions of hygiene you can avoid the doctor's doses.)
2. Prends toujours tes repas à heures régulières,
Ayant débarrassé tes mains de leurs poussières.
(Always take your meals at regular hours,
Having first relieved your hands of their dirt.)
3. Sois joyeux à l'idée de manger un bon plat :
Ton estomac secrète alors sans être las.
(Be happy at the prospect of eating a good meal,
For then your stomach secretes without becoming tired.)
4. Ecoute : pour avoir mâché ses aliments
Avec grand soin, Fletcher vécut quatre-vingt ans !
(Take heed : Because he chewed his food
With great care, Fletcher lived eighty years !)
5. Du berceau à la tombe utilise le lait ;
A lui seul il nourrit ; c'est l'aliment complet.
(From the cradle to the grave use milk ;
By itself it nourishes ; it is the complete food.)

¹ The following commandments are given in French and translated literally.

6. Aime avec élection animal, fruit, légume;
L'homme trop exclusif se voue à l'amertume.
(Like equally meat, fruit, vegetable;
The too exclusive man dedicates himself to bitterness.)
7. A viande faisandée, à repas épicé,
Sans regrets tu devras sagement renoncer.
(Gamey meat and spiced dishes,
You should wisely renounce without regret.)
8. Paresseux, l'intestin réclame-t-il une aide?
Au lait caillé, aux fruits, aux légumes il cède.
(Indolent ones, does your intestine call for assistance?
To curds, to fruits, or vegetables it will yield.)
9. Te plains-tu de diarrhée? Absorbe à faibles doses
Blanc d'oeuf, riz, lait, coings, nèfles ou rien du tout si l'oses.
(Do you complain of diarrhea? Take in small quantities
White of egg, rice, milk, quinces, medlars, or nothing at all if you dare.)
10. Du vin pris au repas stimule l'appétit,
Mais par l'alcool, santé, biens, race, tout périt.
(A little wine with meals stimulates the appetite,
But through alcohol, health, wealth, race, everything perishes.)
11. Bois un verre d'eau claire au coucher, au lever;
Dehors promène-toi ton repas achevé.
(Drink a glass of clear water on going to bed and on arising;
Take a walk outdoors when your meal is over.)
12. Evite tous excès de mets ou de boisson;
Ils épuisent le corps et troublent la raison.
(Avoid all excess of food or drink;
It weakens the body and befuddles the mind.)

It was also, in 1905, with a view to instruction and propaganda that I, my teacher Landouzy, and my brother Henri Labbé, formulated our "Tables of alimentary education." An inquiry into the dietary of a certain number of Parisian workmen and clerks of both sexes, who came for consultation to the Laennec hospital, convinced us of the importance of a bad dietary in preparing the ground for a tuberculous invasion. We had emphasized the principal errors of this morbid dietary: the abuse of meat among working people, the abuse of alcohol, the belief that meat and alcohol produce vigor; the lack of starches and of sugar, the scorn of rice, of macaroni and spaghetti, of sweetened side dishes among the families of working people; the exaggerated taste for greens, gherkins, and condiments, which have no dietary value, among anemic and dyspeptic young working girls; the too frequent omission of breakfast, which should always be taken before going to work or exposing oneself to the outdoor cold.

Having seen the danger, we sought to put the working people on guard and to accomplish their alimentary education. It was toward this end that we drew up our tables. In these we have exact directions as to the quantity and quality of the foods which should enter into

the diet, taking into account the weight and relative stoutness of individuals, the sex, and the occupation. We added to it an "Indicator of the nutritive and market values of the ordinary foods," in which, in schematic form, may be compared the energy value of meat, eggs, vegetables, cereals, and fruits, the relative importance of each of these foods with regard to protein, fat, carbohydrates, and mineral substances, and finally, the cost price of energy according to whether it was derived from one or another kind of food.

We thus showed the dietary advantages of potatoes, in which 100 calories cost only 1 centime; those of rice, of bread, of sugar, of lard, of leguminous plants, of salt pork, of milk and butter, among which 100 calories vary from $1\frac{1}{2}$ to 4 centimes; and we showed on the other hand the high price of eggs, of green vegetables, of greens, and of butcher's meat, which furnish the same amount of energy for a sum varying from 16 to 30 centimes, or at least at a price from sixteen to thirty times higher than the potato; we showed also that the potato is the economical food par excellence, while meat and greens are foods de luxe.

During the war and especially during after-war conditions, the cost of food increased in enormous proportions, but the relation between the price of the various commodities has scarcely changed at all, and our conclusions from the economic point of view remain the same. More than ever, among the social classes which feel the hard times most heavily, it is necessary to know the most advantageous foods; more than ever should there be interest in dietary economy.

In making up our tables we addressed ourselves to the working people and clerks themselves, and especially to the women, to the housewives, who are responsible hygienically and economically for the feeding of the family. Many have read our tables, listened to advice which we gave in lectures and in articles, and benefited from it.

Our effort has not been the only one. With a much wider scope, the Society of Nutritional Hygiene, through the voice of its lecturers, has undertaken to spread the right principles among the people. Toward the end of the war, at the time when the food question was becoming more and more difficult, a new organization, the "*Vie moins chère*" (Society for Cheaper Living), was formed under the auspices of M. Gley, with the initiative of Mme. Moll Weiss, to spread among the Provinces the most indispensable information on alimentary hygiene and economy. Stern necessity forced all to see the practical importance of the food question regarded from a scientific point of view. It is therefore urgent to follow up and develop this instruction. This is what M. Henri Labbé and I have attempted to do during the past two years in a course given at the Society of Nutritional Hygiene under the auspices of the National Committee.

But we believe also that this instruction could be begun earlier, and that our tables, revised and brought up to date with regard to prices, could advantageously be introduced into the schools, where they would serve as a text to be used in instructing the older children in the theoretical and practical rules of nutrition.

The necessity of introducing nutritional hygiene into the curriculum is impressed on all minds. The directors of primary instruction and of secondary instruction show a great interest in the matter.

In girl's seminaries nearly all the directors have organized courses in nutritional hygiene, associated or not with courses in domestic science and courses in cooking. The program varies with the different establishments. The best procedure to accomplish the desired end has not yet been given. We believe that it will be found in a combination of elementary theoretical courses with practical courses in domestic science and cooking, for which a space consisting of a simplified apartment and kitchen should be provided.

On this question there are found excellent points in a "Program of household and domestic economy instruction," designed for girls from 6 to 12 years old, published by the French Educational League. The ingenious idea put into practice in the St. Denis and d'Auber-villiers schools was the establishment of a "household day" during which the arithmetic lesson bore on questions of housekeeping (expenses and economies), the science lesson on questions of hygiene and of the care of children, on the nutritive value of foods, on the composition of bills of fare, the lesson in moral philosophy on the duties of the child in the home: the dictation itself could have for a subject the principles of hygiene or the care of children or cooking recipes.

Whatever be the program adopted, it is indispensable that the girls of to-morrow, who are launching out more and more into the conquest of independent, administrative, and commercial positions, filled formerly only by men, shall not forget the management of a home, which, with maternity, is still their fundamental part, their most glorious career in life.

No longer, as in the time of Molière, does affectation for "fine writing" among the "precieuses" tend to cause neglect of domestic occupations; it is to obtain the time to pursue serious studies and to fill lucrative professions that many girls of our time lay aside the cares of housekeeping.

Let us, then, return, if not to boiled beef and broth, at least to savory broiled meat and to succulent roasts, to homemade pastries, to dainty and nourishing side dishes, to preserves and jams, to good recipes which are handed down from mother to daughter. The health of our children, the future of our race, would benefit by it.

It is not only in the school that instruction may be given. The minds of some children of a free-lance disposition are sometimes refractory to whatever is told them by the teacher, while they will accept willingly the homely advice given by their elders and that instruction, not compulsory and without obligation, which life gives them. It is in such cases that posters, pamphlets, newspaper articles, and tracts can be used.

In America this procedure is widely used. Little pamphlets, very brief articles prepared by teachers of alimentary science and stamped with great common sense, have been published in great numbers and distributed either free or sold for a small price. They were issued in profusion during the war. They are on the subjects of the value of milk and the necessity of insuring a supply for the children; of the necessity of economizing on meat and replacing it with other foods; of corn meal and oats and ways of preparing them; of potatoes in the form of bread; of the theory and practice of nutrition; of the diet of laborers and that of sedentary workers, etc.

One of them, in four pages, sums up the essential parts: On the alimentary needs of the child; on the purpose of nutrition, which is to make vigorous bodies, good brains, rosy cheeks, and bright eyes; on the choice of foods; on every-day bills-of-fare and recipes. These tracts are generally published by the Department of Agriculture and the Public Health Bulletin of Massachusetts. We also ought to publish pamphlets of this kind. Unfortunately the time is unfavorable for printing. However, the "Cheaper Living" Society during the last year of the war found the means to issue some of these tracts accompanied with practical culinary advice, which are excellent. It is regrettable that their publication should be stopped.

Together with Henri Labbé, under the auspices of the National Committee, we have begun with a pamphlet of eight pages summing up the most important precepts for the diet of athletes; it appeared at the same time that the Pershing stadium was opened. It would be desirable to continue this work by publishing little pamphlets on the nutrition of school children, the diet of manual laborers and of sedentary workers, the alimentation of mothers and of nurses, the comparative value from the hygienic or economic point of view of certain foods. Every time that a new question arises it would be desirable to have it treated succinctly and brought to the attention of the public: for example, would it not be interesting at this time to show how butcher's meat could be replaced by equivalent foods and to bring out the advantages of refrigerated meat, to teach consumers to pass the butchers by as long as they refuse to lower their prices in accordance with the trend of commodities and propose to make excessive profits to the detriment of the public.

A number of persons are busy along these lines. Among our students in the course of alimentary hygiene, there are some who have become our collaborators and who through talks, lectures, motion pictures, articles inserted in the great daily papers in Paris and in the Provinces, are ably striving to spread the scientific and economic information indispensable to knowledge about nutrition. Their work is good and profitable.

The campaign for nutritional education, of which I have traced the outlines, is directed to the child either directly or through the intermediary of its parents. It is complex, but it is necessary and will not be in vain. All that we do for the children, the future of the race, will bear fruit; the miniature man is endowed with a receptive, intelligent mind, easily molded; he is essentially educable. He acquires good habits as easily as bad ones; he can do a thing hygienically as well as unhygienically. It depends on the environment in which he lives. If he has before him examples of cleanliness and good hygiene, he assimilates them; if he has bad examples, he follows them. At the beginning of life, everything is still on an equal footing with him. He has no innate taste for pernicious things. The child does not like gamey meat; he must have had a long education in bad alimentary habits to give him a taste for it. It is the same for strong alcoholic drinks, which at first offend the delicate senses of the young man, just as morphine brings on nausea before creating an artificial paradise.

If the child has vices, he has acquired them from our example or from the environment in which we live. If he is a drunkard, we are responsible for it.

Inversely, it is curious to see how easily children acquire hygienic habits. Notice with what abhorrence some children refuse to drink from a glass or eat from a spoon used by another person; how others, in spite of being greedy, scorn a piece of candy which has fallen on the ground; how all are filled with disgust at the idea of finding a worm in a piece of fruit. Alimentary hygiene taught through example at this period of life is solidly implanted. Hygienic acts become unconscious, almost instinctive, and direct the child's life.

It is very different with the adult, full of inveterate bad habits and crammed with prejudices; he is difficult to correct and is never perfectly reeducated.

Surgeons know well that asepsis can not be learned after a certain age; it is comprised of reflex acts which have been inculcated in them since the very beginning of medical studies. The cleanliness of a surgeon depends on his first training. It is the same for alimentary hygiene.

Alimentary education is useful not only to individuals; it is also profitable to the general public. Through it little by little the

habits of men will be changed and certain diseases which arise from alimentary vices will disappear. Already, because the excesses of meat eating to which our fathers gave themselves up are exceptional to-day, gout has become very rare; it is doomed to disappear. Obesity, sick headache, and some diabetes connected with overeating will be suppressed when men resign themselves to moderation. They had practically disappeared in Germany under the influence of the forced alimentary restriction during the war.

Alcoholism, also, with its hepatic, nervous, and mental symptoms, should vanish if the nations had the firm will to abolish it. There would remain only a certain number of hopeless drunkards—just as there are some morphine addicts throughout the world.

As regards the infectious diseases, of which the germ is introduced through the digestive tube—typhoid fever, cholera, and dysentery—and as regards enteritis, brought on by intestinal parasites, they are already less frequent than formerly, and they are destined to disappear through the progress of nutritional hygiene and especially through the use of sterilized drinking water. Tuberculosis itself, in so far as it is related to the diet in infancy, should diminish. Such is the importance of the results which we may expect from nutritional education. If it is given early and very generally, if it is addressed to the children and to their mothers, it will efface little by little from pathology a series of diseases which result from dietary errors, and it will improve the health of individuals, and the beauty of the race. It will accomplish the double purpose, both individual and social, which the philosopher Guyau assigned to a good education. It is, therefore, with good reason that we make it one of our first considerations.

A FIFTY-YEAR SKETCH-HISTORY OF MEDICAL ENTOMOLOGY.¹

By L. O. HOWARD, M. D., Ph. D.

[With 10 plates.]

A real history of medical entomology would require a year or more in its preparation and should be done, perhaps, by two men, the one a medical man (a pathologist), and the other an entomologist, since a complete history, written by one or the other, would unconsciously emphasize the importance of one side. But the time has come for the preparation of a consecutive account of the main features of the extraordinary development that has taken place in the past few decades; and this article, however faulty and however hastily done, is an attempt to do this. In any history there is always a balancing of the advantages and the disadvantages of a too near or a too distant view of events, and if the present view is too near it may at least contain suggestions for the consideration of the future historian.

In 1871 the idea that any specific disease might be insect borne was not mentioned in any of the standard medical treatises. In this direction the world was as ignorant as it was 300 years earlier, when Mercurialis suggested the idea of food contamination by flies coming from the excretions of those dying from the "black death" to visit exposed food supplies. Even this perfectly obvious conclusion of the old Italian physician made little impression, and, although occasionally repeated from time to time through the years by one observer or another, mainly in reference to Asiatic cholera, flies generally, were regarded as harmless nuisances, and, perhaps, even as beneficial as destroyers of offal in their maggot stage.

We can hardly blame the workers in medical sciences before the days of microbiology for indifference or for lack of vision in this direction, in spite of the fact that here and there in different parts of the world there existed among the people popular beliefs which connected certain insects with disease. It was so in India, in Africa,

¹ Reprinted, with slight alterations, by permission of the American Public Health Association from "A half century of Public Health—Jubilee historical volume of the A. P. H. Assoc.," N. Y., 1921 (pp. 412-438).

in South America, and even on the Roman Campagna, a home of malaria, the poor peasants long ago connected the idea of mosquitoes with the idea of fevers.

But there were a few men before Pasteur's discovery of pathogenic bacteria, and long before anyone had dreamed of disease-carrying protozoa with alternate hosts, who had imagined in a way the connection between mosquitoes and yellow fever. Louis D. Beauperthuy, a French physician long resident in the West Indies, as early as 1853 elaborately argued that yellow fever is conveyed to man by mosquitoes, but he supposed that the insects carried the virus from decomposing matter which they had visited. Even earlier, in 1848, Dr. Josiah Nott, of Mobile, had contended in a published article that the specific cause of yellow fever exists in some form of insect life.

The first decade of our 50 years was almost passed when the first great discovery in medical entomology was made, a discovery which, although it had no connection with bacteria or protozoa, led directly to others, and in fact opened the way to the vast field of discovery in which many men of many countries have worked and are now working. This was the discovery by Dr. Patrick Manson of the full life round of certain filarial worms, in which certain mosquitoes play a vital part. So revolutionary was this work and so unimaginable in its results even to intelligent practitioners that the late medical inspector, J. S. Ames, of the United States Navy, has told me how the Navy surgeons of different nations, coming together by chance on the China station, "used to chaff crazy Pat Manson about his mosquito filaria ideas." Manson's discovery was brilliant and revolutionary. It was the result of long work under trying conditions and in the face of a discouraging lack of interest and even serious doubts as to his perfect saneness on the part of his colleagues, and he deserves even greater honor than was given to him, although he has been hailed as a pioneer and a great leader by the medical profession and the scientific world at large. His work led directly to the great achievement of Ross in regard to malaria.

But before we take up Ross's wonderful work we must for an instant refer to an extraordinary paper by A. F. A. King, a Washington physician with a speculative mind, who published in 1883 an extended argument to prove that malaria is carried by mosquitoes. As a closely reasoned argument this paper was as nearly conclusive as would be possible without actual experimental evidence. But the time was not ripe for the acceptance of this idea, and laboratory technique and microbiological science were not far enough advanced to allow even promising confirmatory experimentation. I am inclined to pity myself when I remember my incredulous frame of mind when Doctor King broached his theory to the late C. V. Riley and myself



SIR PATRICK MANSON.



before he read his very notable paper before the Philosophical Society of Washington in the early eighties. It is worthy of note that although several prominent medical men were present at the meeting, including the late Drs. J. S. Billings and Robert Fletcher, the paper fell utterly flat as to encouraging discussion. And when published a number of months later in the old *Popular Science Monthly* for 1883, the article attracted little attention, and, so far as I know, received none of the favorable comment it deserved until George H. F. Nuttall recognized its remarkable character 16 years later and reviewed it at some length in his admirable summary "On the rôle of insects, arachnids, and myriapods as carriers in the spread of bacterial and parasitic diseases of man and animals," in Volume VIII of the *Johns Hopkins Hospital Reports* (1899). It is certain that at the time King formulated his mosquito-malaria theory he had no knowledge of Laveran's discovery in 1880 of the causative organism of the disease or of Manson's discoveries regarding the carriage of filariasis by mosquitoes, since he would undoubtedly have added another strong argument to the 12 he so admirably formulated had he possessed this information.

But here we must leave malaria temporarily in order to discuss briefly in its chronological order the extraordinary and basic discoveries of Theobald Smith with regard to the Texas fever of cattle.

The so-called Texas or Southern cattle fever had long been known as a disease transmitted to northern cattle by cattle coming from the southern regions of the United States. The region from which infected cattle came was large and well defined and included most of the Southern States. Southern cattle themselves as a rule were free from any signs of disease. Cattle coming from the South in the winter were harmless but when they were brought North during the summer, the disease came with them. Curiously enough, it did not seem to be an infection which was communicated directly from southern cattle to northern cattle, but that the southern cattle infected the ground over which they passed and then when the northern cattle grazed over this same ground, they caught the fever.

It had long been the belief among certain cattle raisers in the West that ticks were the cause of this fever and that they were carried and scattered everywhere by southern cattle. Many, however, disbelieved this theory. Observations confirmatory to the tick theory, however, had been made; for example, it was noticed that when southern cattle had been driven for a considerable distance, after a time, they lost their power to infect pastures. Moreover, it was noticed that after southern cattle had passed, the disease did not appear among northern cattle grazing on their trail until 30 days or thereabouts had elapsed.

Our knowledge was in this condition, when the investigation of the disease was taken up seriously by the Bureau of Animal Industry

of the United States Department of Agriculture. Dr. Theobald Smith was a young man who had graduated at Cornell University in 1880 and had afterwards taken his degree in medicine at Albany. He had taken special studies which admirably fitted him for this work and became connected with the service at Washington. In 1889 he succeeded in discovering a peculiar microorganism in the red blood corpuscles of an infected cow which corresponded in every respect with what one would expect as the true cause of the disease. Doctor Smith was associated at that time with Dr. F. L. Kilborne, who had charge of the field experiment end of this work, and he soon succeeded in showing that the cattle tick was somehow necessary to the transmission of the disease. These observations were fully confirmed in 1890. In the autumn of that year it was found that when young ticks which had been artificially hatched were placed on cattle there was a sudden astonishing loss of red blood corpuscles which could by no means be explained by the simple abstraction of the blood. Additional experiments showed that the fever was caused by putting recently hatched cattle ticks on susceptible cattle. These results were confirmed in the summers of 1891 and 1892.

Here again results confirmed an idea current among the people but not indorsed and even derided by scientific men. In 1868 Dr. John Gamgee, who had been brought over from England to study the plague for the United States Government, wrote:

The tick theory has gained quite a hold during the past summer, but a little thought should have satisfied anyone of the absurdity of this idea.

The great importance of Smith's work consists in the demonstration that the infection is carried from the adult ticks into the eggs and from them to the young and that they later introduce the virus. The first thing that occurred to the discoverer was that the tick drew out the causative organism from the blood of the cattle and distributed it on the pasture and that the cattle ate it with their food; but it was not until 1891, when he accidentally found that he could obtain eggs from the ticks in confinement, that it was possible to begin experiments to prove the transmission by the bite. His discovery of the causative organism had enabled him to recognize mild cases of the disease produced experimentally, since only by an examination of the blood microscopically and with the blood counter could such a diagnosis be made.

The remarkable benefits to the people of the United States that have resulted from this discovery are, of course, well known. Southern cattle after having been "dipped" to free them from ticks can now be carried north beyond the "tick line" without the slightest danger that the southern fever will be transmitted to northern cattle. And much more than that, the southern country is being rapidly freed from the cattle tick, and by rotation of pasturage and

by dipping county after county has been retrieved from quarantine and now a vast area, formerly dangerous, is fever free. Curiously enough the old fever quarantine line corresponded closely to the dividing line between the upper and lower austral life zones on Merriam's early life-zone maps of the United States. Theoretically, therefore, the cattle tick is a lower austral form and can more easily be exterminated from its more northward range. But cattle culture can now be carried on with profit in many regions of the South where diversified agriculture has become a necessity.

This in itself is a noteworthy result of Smith's discovery, but biologically it is of the very greatest importance as the pioneer discovery of a blood-inhabiting protozoan in its dual relation between an articulate and a mammalian host. It is true that the cattle tick is not, strictly speaking, an insect, but it is closely related to the insects and is popularly called one, so that this demonstration, first described in full in 1893, ranks as the second great discovery in medical entomology.

While Smith was completing his college course at Cornell, Dr. A. Laveran, a French Army surgeon, was studying malaria in Algeria and succeeded in 1880 in demonstrating an ameboid organism in the blood of malarial patients, which he studied at length and showed to be the causative organism of the disease, which thus became established as a parasitic malady. The details of the life cycle of this organism as it occurs in man were traced by Laveran after the discovery of the true cause of the disease, and there was much speculation as to the manner in which it is transferred to healthy people. The drinking of contaminated water was an early suggestion and there were others, but experimental work failed to prove their truth. Laveran himself eventually suggested that the parasitic organism might be carried by mosquitoes, but Manson, after his success with *Filaria*, insisted upon the necessity for experimentation with these insects and formulated the hypothesis that they might be the necessary secondary hosts. It was, in fact, largely due to Manson's suggestions that Ronald Ross, then a surgeon in the Indian Medical Service, began his studies.

The details of Ross's work have now become well known among the medical profession and those engaged in sanitary work. Starting with nothing but a theory and a knowledge of the appearance of the parasite after it appears in the blood of man, but with no knowledge whatever of how it might look in another stage of its development or whether it might be found in one kind of mosquito and not in another kind, Ross spent two years and a half of the most strenuous work before he solved the question and found the parasites among the cells of the stomach of what he termed "dapple-winged mosquitoes." This result was reached in August, 1897, and after its

announcement, many workers attacked the problem and confirmation rapidly followed. The complete life history of the parasite was worked out and the mosquitoes of the genus *Anopheles* were definitely shown to be the sole means by which malaria is transmitted from man to man. The Italian workers, Grassi, Bignami, and Bastianelli, began to work along the same lines shortly after Ross had begun his investigation and for a long time contended that the credit for the establishment of relations between *Anopheles* and human malaria belonged to them, since Ross's first work was done with mosquitoes of the genus *Culex* and a malarial disease of sparrows. The Nobel Prize, however, was awarded to Ross in 1902 after a careful examination of the matter of priority and of late the Italians have advanced no claim. In fact, talking with Angelo Celli in 1910, I jocularly referred to his "old friend Ross" (since Ross had been particularly harsh in his criticism of the claims of the Italian school) and Celli replied to the effect that it was all smoothed over and that he had contributed a chapter to Ross's big book on malaria which had then just been published. It seems that Ross knew nothing of Theobald Smith's discovery of the blood inhabiting protozoan of the Texas fever of cattle and of its established vital relation with the cattle tick, so that his work with malaria was absolutely original with him and so far as he knew was the first accomplishment of this nature so far as protozoan parasites were concerned. The importance of his work can not be overestimated. It was one of the great discoveries in biological science applied to medicine and will eventually mean more for the health and happiness of mankind than almost any discovery that has ever been made. Ross, like Manson, was knighted and has lived to enjoy many honors and to see in many directions the vast fruits of his discovery.

Practical work based on Ross's discovery was immediately begun in different parts of the world. He, himself, headed an expedition to Lagos on the West Coast of Africa and by putting antimalaria measures into effect reduced the malaria incidence very greatly. Elsewhere the same thing was done. The governors of the British colonies, especially the authorities of the Crown Colonies, did not act with sufficient rapidity and enthusiasm to satisfy Ross, who felt, with his crusader's spirit, that they should have shown more. He published a little book called "Mosquito Brigades" in 1901, in which he gave explicit directions, as a result of his field-work, as to the best means of organizing and operating antimalaria campaigns, especially in the Tropics. In this book he said severe things about the dilatoriness of British officialism in sanitary matters. Three years previously I had published a bulletin on mosquitoes and antimosquito work in which I referred to Ross's discovery and detailed the best measures for fighting mosquitoes, and a number of bits of experimental work

were done in several parts of the United States which were detailed in the book entitled "Mosquitoes, How they Live, How they Carry Disease, and How they May be Destroyed," which was published in 1901.

It is astonishing how rapidly conviction followed this great discovery and how widespread the belief in its soundness soon became. The leaders of the medical profession adopted it at once and doubters were astonishingly few and were soon silenced. Certain State health officers in this country took it up and preached it. As early as 1898 I was invited to address the section on medicine of the American Medical Association at its annual convention at Atlantic City on the subject of the malarial mosquito, and no serious objections to the so-called "theory" were in evidence. The only feeble note of protest that I remember was at New Orleans in December, 1905, at a meeting of the section of physiology and experimental medicine of the American Association for the Advancement of Science during a symposium on insect-borne diseases. No one present will ever forget the dramatic manner in which the late Doctor Chaillé crushed the unfortunate speaker.

As always, the center in this country of early adoption and dissemination of this wonderful discovery was Johns Hopkins University.

Dr. William S. Thayer went to Italy and studied the work on the Roman Campagna and in the laboratories of Grassi and Celli. He returned to Baltimore and began an enthusiastic campaign of education. Dr. Walter Reed, of the United States Army; Dr. Jesse W. Lazear, and Dr. J. C. Carroll—all with Johns Hopkins affiliations—absorbed the new ideas with interest, and from this group of men came the next great discovery in medical entomology.

The war with Spain had just been completed. The American Army of occupation was in Cuba; the then Surgeon General of the Army, Dr. George M. Sternberg, was a bacteriologist and had been a student of yellow fever. Sanitary conditions in Cuba were very bad. The possibility of an epidemic of yellow fever among the American troops was very great, and malaria was rife on the island. Therefore General Sternberg formed a commission, composed of Doctors Reed, Carroll, and Lazear, and added to their number Dr. Aristides Agramonte, a Cuban physician educated in the United States, and instructed them to investigate sanitary conditions in Cuba in as thorough a manner as possible, paying special attention to yellow fever.

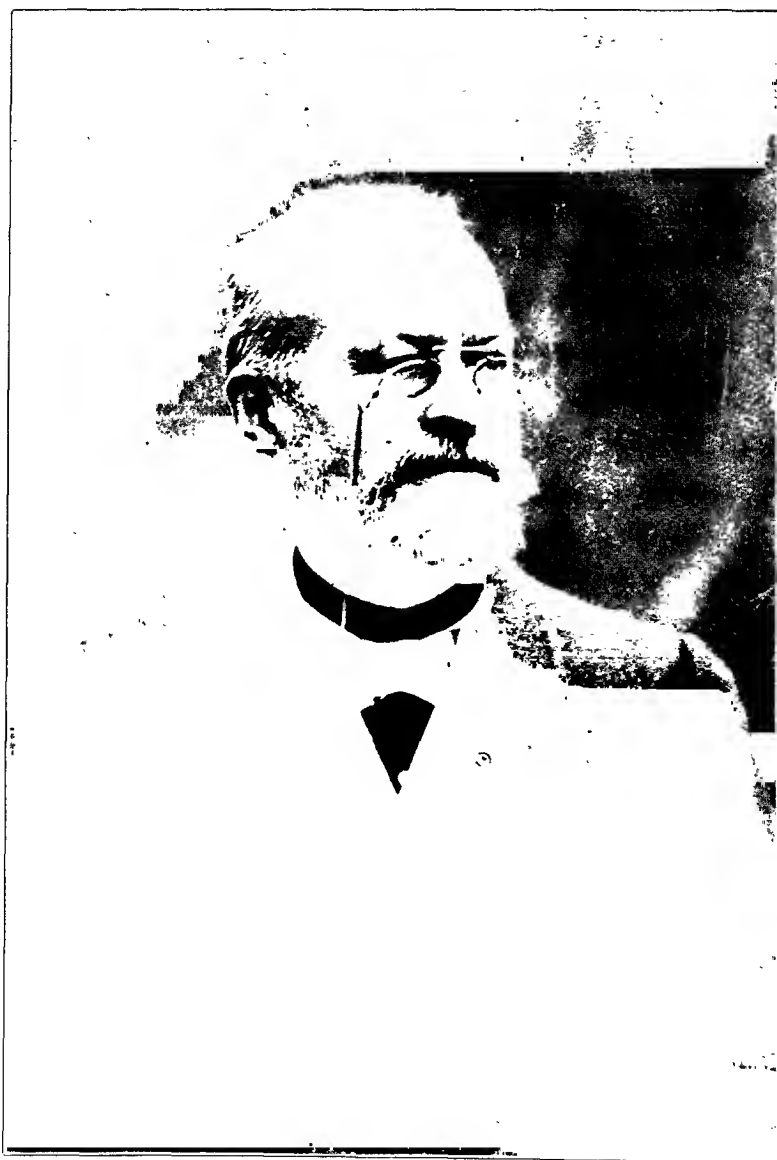
Now it happens that as early as 1880 a Cuban physician of a speculative turn of mind, a man of imagination (of the A. F. A. King type), named Carlos J. Finlay, had been filled with the idea that yellow fever is carried by mosquitoes. Not content with theorizing, he put his ideas to the test; but, working single-handed and in defiance

of accepted views, and knowing nothing of protozoology and little of bacteriology and laboratory methods, he failed to bring forward any convincing proof, although his experiments were in a high degree suggestive. He had, however, selected the exact species of mosquito which was eventually proved by the United States Army Commission to be the true vector of the disease, namely, *Culex fasciatus*, as it was then called—the most abundant of the household mosquitoes of Cuba. Sternberg, who had been a member of an American commission to study yellow fever in Cuba at that time, met Finlay and was familiar with his experiments, but neither at that time nor at any other, after the Reed commission results were gained, is there any evidence to show that Sternberg was at all favorably impressed by Finlay's theory. The fact, however, that Finlay's ideas were ultimately proved to be true and that his experiments failed only in detail and that he selected the exact species of mosquito as the probable carrier of the disease, entitled him to great credit, and he is to-day acclaimed throughout all Latin America as the real hero of the mosquito yellow-fever discovery. With this, however, North America and most of the rest of the world does not hold, since he did not prove his case.

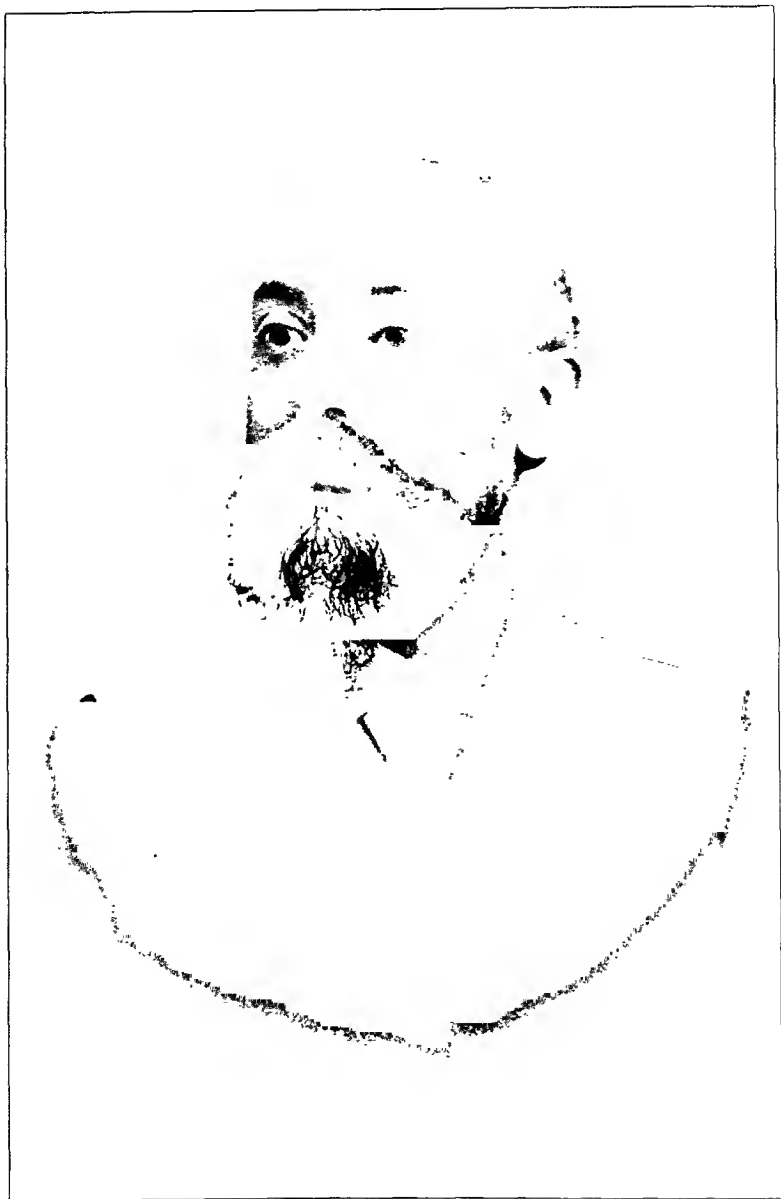
Reed, knowing Finlay's theory and filled with enthusiasm over the results of Ross's investigation and those of the Italians, went to Cuba with the determination to give the mosquito idea a thorough test. Lazear I knew from calls which he had made at my office with Thayer to find out what I knew about the malaria mosquitoes; and before they went to Cuba on this mission, Reed and Carroll spent some time in the Bureau of Entomology studying *Culex fasciatus* and learning to differentiate it from other mosquitoes that they were likely to meet with in Habana.

The story of their work for the next two years is known to all the world. By a series of most carefully guarded experiments on volunteering American soldiers—experiments which the physicians of Habana, experienced in every phase of yellow fever, were invited to view and to criticize—they succeeded in showing that the current idea that the fever is carried by infected clothing, bedding, and other articles was utterly wrong, and that it is carried solely by the bite of the common house mosquito of tropical America, *Stegomyia fasciata*.² Announcements of their results were made in two papers at intervals of a year, and while the first was received with some doubt by the London Lancet, the second was so conclusive, although wonderfully modest and matter of fact, that the acceptance of the result was general and enthusiastic. Later work by others only confirmed the conclusions reached by Reed and his colleagues, and

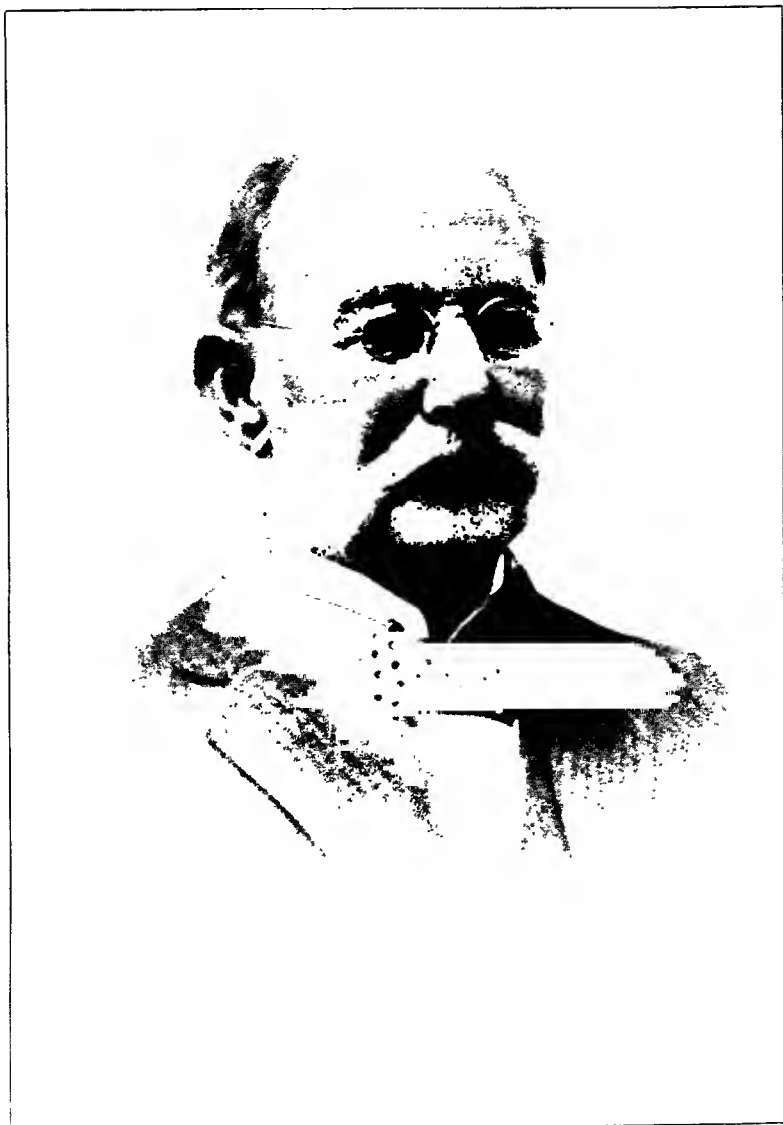
² Now known as *Aedes calopus* or *Aedes argenteus* or, strictly, *Aedes aegypti*.

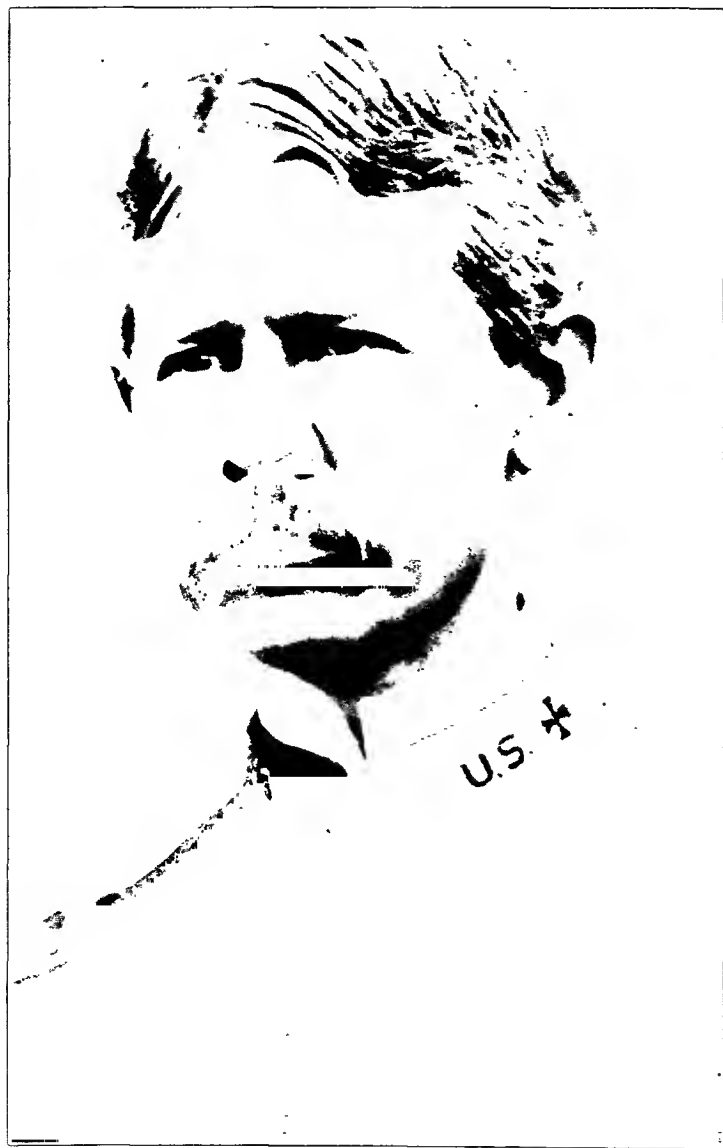






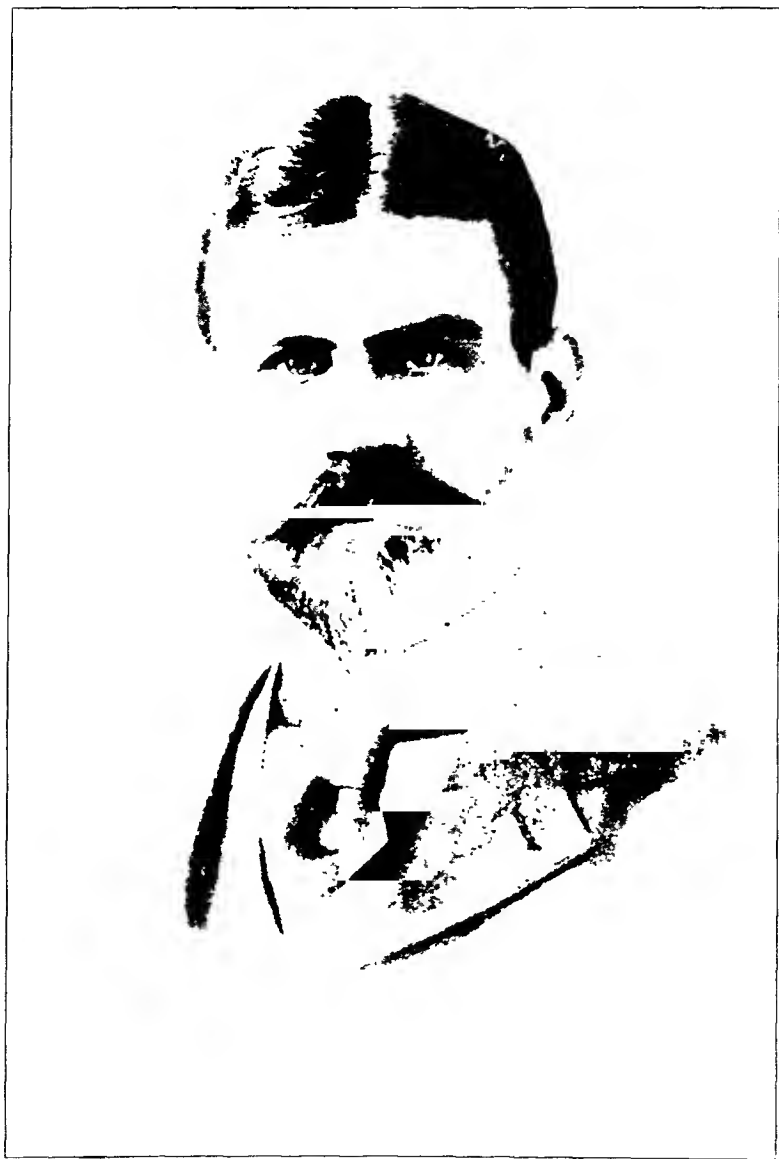
DR. A. CELLI.





DR. WALTER REED.





DR. J. W. LAZEAR.



DR. HOWARD T. RICKETTS.

to-day the world is in a fair way to be completely rid of yellow fever, one of the greatest scourges of mankind in warm countries.

All through the progress of this work Doctor Reed was in constant correspondence with Washington. He returned to the States in October, 1900, to read before the annual meeting of the American Public Health Association the first announcement of the results gained from his first series of experiments, and later returned to Cuba to carry out the second and conclusive series. He wrote me frequently and, of course, corresponded regularly with Surgeon General Sternberg, and the Surgeon General and I used to meet after office at the Cosmos Club to compare notes and read to each other the letters we had received from Cuba. One of my most highly treasured possessions is a final letter from Reed, written January 13, 1901, when he was confident that he had proved his case beyond cavil.

He said: "Of course, you have already heard from General Sternberg of our complete success in repeating our former observations. The mosquito theory for the propagation of yellow fever is no longer a *theory* but an established *fact*. Isn't it enough to make a fellow feel happy? Anopheles and Culex are a gay old pair. What havoc they have wrought on our species during the last three centuries!" and finished by stating that with the aid of antimosquito measures, which he was good enough to say that I had developed, yellow fever would be wiped off the earth.

The control of yellow fever by antimosquito work was soon demonstrated in a very big way. The army of occupation in Cuba took up at once the task of ridding Habana from the disease, and incidentally from malaria. How well this was done all the world knows, and the active director of the work, Doctor Gorgas, stepped into the light of fame.

Only a few years later the United States staged a very conclusive demonstration. In the early summer of 1905 yellow fever broke out in a certain quarter of New Orleans. The number of cases rapidly increased and an epidemic apparently comparable with the disastrous one of 1878 had begun to spread. The United States Public Health Service took command of the situation early in June and, under the direction of Dr. J. H. White, carried on a perfectly thorough antimosquito campaign. The results were striking. The fever stopped spreading. Very few new cases developed and, comparing the figures of deaths in that year with those of 1878 in New Orleans, there was a plainly convincing saving of 4,000 lives, due to the discovery of Reed and his colleagues.

It will be unnecessary to carry the story of yellow fever demonstrations further. Rio de Janeiro was soon rid of the plague by the intelligent and energetic efforts of Oswaldo Cruz and his colleagues. Admirable work was done in Mexico under the direction of Eduardo

Liceaga and it was not long before all of this was overshadowed by the magnificent results gained by Gorgas in his administration of the sanitary affairs in the building of the Panama Canal. The results of Gorgas's work were to show that the Tropics may be inhabited by the white race, a fact of tremendously far reaching importance to the future of the world.

Unlike Sir Patrick Manson and Sir Ronald Ross, on whom honors have been showered and who are still living to enjoy the fame that has come to them, the three American members of the commission are dead. Lazear succumbed to the fever during the progress of the investigation, Reed not long after, and Carroll a year or so later, both indirectly as the result of their Cuban work.

Reed died too early to receive the Nobel prize, which probably would have been awarded to him, and I happen to know, from a conversation with Sir Ronald Ross and Sir Rupert Boyce in Liverpool, in 1905, that Carroll's name was under consideration for this prize just before his death.

The actual causative organism of yellow fever was not found by the Reed Commission, nor was its development in the mosquito ascertained. They found that the blood serum of a patient retained its toxicity after passing through a Birkfeld filter and concluded that the causative organism must be ultramicroscopic. Recently, Noguchi, of the Rockefeller Institute, has isolated a spirochaete which he considers to be probably the true cause of the disease and this opinion is shared by Simon Flexner and other prominent pathologists, but the well-known authority on yellow fever, Juan Guiteras, of Habana, has just analyzed the results and shows that there is still some room for doubt. At any rate just what happens to the organism in the body of the mosquito remains to be determined.

The next most important discovery in this direction related to dengue or breakbone fever, a disease common in semitropical and tropical countries, common in the West Indies, and in the southern United States, and found also in southern Asia, in the Philippines, and in the South Sea Islands, and in the countries about the eastern end of the Mediterranean. In 1902 Doctor Graham, working in Beirut, Syria, showed that the disease was not contagious in the absence of mosquitoes, but that isolated persons contracted the disease when bitten by mosquitoes which had bitten dengue patients. Later Ashburn and Craig, of the United States Army, working in the Philippines, showed with mosquitoes bred in the laboratories and fed upon dengue patients, that the insects will transmit the disease after a period of three days. The mosquitoes used by Graham in Syria were the cosmopolitan water barrel mosquitoes of the tropics *Culex fatigans* (now called *C. quinquefasciatus*), while the yellow fever mosquito, *Aedes calopus* (or better, *aegypti*) carries the disease in

the Australasian life zone. In Formosa, Koizumi has incupated *Desvoidea obturbans* in the same relation.

The spirochaetes, protozoal organisms of wide distribution, have, however, been shown to be the cause of other diseases of man and animals and to be insect-borne, but in nearly all of these the arthropod carrier is a tick rather than a true insect, and it is interesting to note that with at least one of these the infected tick transmits the disease to its offspring just as Theobald Smith found to be the case many years earlier with the Texas fever of cattle.

The series of discoveries of spirochaete-tick diseases began shortly after the establishment of yellow fever mosquito relation, by the findings of Ross and Milne in Uganda, and Dutton and Todd in the Congo, in 1904, of the spirochaete cause of the so-called "African relapsing fever" and its tick vector—*Ornithodoros moubata*. That this fever resulted from the bite of a special tick was long known to the natives of Africa, but just as in the case of the *Nagana* disease of cattle, which will be referred to shortly, the fever was supposed to be due to some special virulence of the tick. In this case the carrier occurs abundantly in native huts and feeds upon birds and mammals as well as upon man, resembling the bedbug in that it works by night.

Another spirochaete disease is the "European relapsing fever," and as early as 1897 Tietin infected monkeys with this disease by inoculating them with bedbugs which had fed upon a patient 48 hours earlier. Therefore bedbugs are supposed to be the carriers of this disease, although the evidence is not complete.

In 1903, however, Marchoux and Salimbeni, working in Brazil under the auspices of the Pasteur Institute of France, secured conclusive evidence of the transference of another spirochaete disease, known as the spirochaetosis of domestic fowls, by a tick known as *Argas persicus*. Still another proved relation of the kind is that of the spirochaetosis of cattle in the Transvaal, where the disease is carried by a tick known as *Margaropus decoloratus*.

Even antedating the work of the yellow fever commission was the extremely important work of Col. David Bruce, of the British Army, with the so-called *Nagana* or tse-tse fly disease of cattle in Africa. In this case the causative organism was found to be another type of protozoan of the genus *Trypanosoma*, and it was this organism, transmitted by the bite of a tse-tse fly from sick cattle to healthy cattle which caused the disease which had previously, just as in the case of the "African relapsing fever," been attributed solely to the virulence of the bite, "fly sickness of cattle" having been known to all African explorers. Here, then, is another group of microorganisms which cause disease in warm blooded animals and are transmitted by insect bites. In this case it was long a matter of doubt

as to whether the fly was simply a mechanical carrier of the pathogenic organism or whether it was a necessary secondary host. This point was partly cleared by Koch, who discovered what he considered to be sexual forms of the trypanosome in the intestine of the fly, but Kleine in 1909 succeeded in finding the different stages of the parasite in the intestine of the insect and proved that part of the life cycle of the insect must occur in this secondary host.

Bruce's discovery and the work of others who followed him in the study of the Nagana disease led directly to the discovery of the cause of the terrible sleeping sickness of man in Africa by Dutton in 1902, which was confirmed by Castellani a little later. When this discovery was announced the Frenchman, Brumpt, and Sambon in England advanced at once the theory that this disease is also transmitted by a tse-tse fly. Their argument was based upon Bruce's discovery with the Nagana and also upon the geographic distribution and epidemiology of the disease, and their theory was abundantly demonstrated not long after by practical experimentation. In this case Sambon was much more fortunate than he was some years later when he advanced the theory that Pellagra is carried by the black flies of the genus *Simulium*, which was afterwards abundantly disproved.

The serious and fatal disease called "Sleeping sickness" had been known among the natives of parts of Africa for very many years. The earliest published account that has been found was by a naval surgeon, John Atkins, in a book entitled "Physical Observations on the Coast of Guiney," published in 1741. For a long time the disease seemed to be limited to West Africa, but with the opening up of the interior it found its way into Uganda with terrible results. In 1901 it was reported by Dr. Albert Cook, of a missionary society, that 200 natives had died and thousands appeared to be infected on Buvuma Island. The disease spread with dreadful rapidity and the Government became intensely alarmed. A commission was sent out from England under the auspices of the Royal Society, and such men as Low, Christie, Castellani, and Sir David Bruce began an immediate investigation, which has continued without interruption (except for the period of the Great War) until the present time. An international sleeping sickness congress was held in London in 1907, which was attended by the most eminent pathologists and parasitologists of many nations, including especially those having African colonies. During all the early stages of the investigation and for a number of years after it was discovered that the disease was carried by the tse-tse flies, field investigations were carried on exclusively by medical men. E. E. Austen, of the British Museum, a well-known entomologist, especially skilled in the diptera (the order to which tse-tse flies belong) was consulted as to the taxonomy of the

insects and as to their probable biology, and Professor Newstead, of the Liverpool School of Tropical Medicine, another competent entomologist, was also consulted. But a new element was added to the investigation when W. F. Fiske, a former expert of the United States Bureau of Entomology, was employed by the Tropical Diseases Bureau, of London, in 1911, and proceeded with a competent expedition to Uganda, where he studied the problem from the viewpoint of his broad experience in field entomology until the outbreak of the Great War. In 1919 he returned to Africa, where he is at present. His preliminary reports have been published and are of great interest from a broad biological point of view as well as in their practical suggestions. It will be impossible to dwell at further length upon Fiske's work in view of the interesting and important investigations that have been carried on by an army of other observers, and it is especially mentioned here because he is the first American broadly trained in economic zoology to give his entire attention to this problem.

The problem of the control of sleeping sickness by the control of the breeding places of the fly, or perhaps of its other hosts in the shape of wild animals, has not yet been settled, but it is hoped that the numbers of the flies may be greatly reduced by the destruction, or the alteration in the character, of its present breeding places or by the preparation of attractive breeding places where it may be exterminated in the pupa condition. Fiske predicts that with the settlement and cultivation of the country the disease will eventually disappear.

We must now return chronologically to another tick disease, namely, the Rocky Mountain spotted fever of man. For the past 48 years a disease which has come to be known as Rocky Mountain spotted fever has been known in portions of Montana and Idaho, and cases have also been reported from a number of other Western States, including Washington, Wyoming, Utah, Nevada, Colorado, California, and Oregon. It is characterized by chills and fever and a characteristic skin eruption. The mortality widely differs in different localities, ranging from 4 per cent in Idaho to as high as 75 per cent in the Bitter Root Valley of Montana. The credit for the full establishment of the relation between the disease and certain ticks is given to Dr. H. T. Ricketts, who conducted carefully guarded experiments in 1906 which indisputably proved the relationship. Ricketts himself, however, gives the credit for the first experimental evidence in support of the tick hypothesis to McCalla and Brereton, who conducted two positive experiments a year earlier. As early as 1902 Wilson and Chowning had reported the causative organism of the fever to be related to that which causes the Texas fever of cattle, but Stiles after carefully working on the problem in 1905 failed to

confirm this conclusion. Much more recently Wolbach (1919) has found an organism which he has described as *Dermacentroxenus rickettsi*, which he considers to be the cause of the disease. He finds that it is intracellular in mammals and in ticks and intranuclear in ticks. It is reasonably certain that some of the native small animals furnish the reservoir of the disease and the destruction of ground squirrels and the dipping of domestic animals to destroy ticks have been tried with good results in the Bitter Root Valley. The tick most closely associated with this disease is *Dermacentor andersoni* Stiles (*D. venustus* Banks), but it has been experimentally shown by Maver that the disease may be transmitted experimentally by several species of ticks.

The Rocky Mountain spotted fever investigation has been marked by the martyrdom of several of the investigators. Dr. T. B. McClintic, of the United States Public Health Service, died of the fever while engaged in its investigation, and Dr. A. H. McCray died in the same way later while working for the Montana State Board of Health. Doctor Ricketts himself, to whom the confirmation of the tick relation in this disease is due, while he passed successfully through his work with spotted fever, died later of typhus fever in Mexico while studying the relation of lice and typhus, which will be treated in a later paragraph.

There has been no systematic arrangement of the accounts so far given of the discovery in the carriage of disease by insects, but I have considered them rather chronologically, following one account of a discovery by the story of the next one. But, arriving now at approximately the middle of the first decade of the present century, the work in this direction all over the world has been so intense and discoveries have been so various, or have followed one another so rapidly, that any strict chronological sequence must be abandoned and, in fact, it will be possible to touch only briefly upon a few of the principal discoveries.

Antedating the investigation described in the last few paragraphs, were the experiments in the transmission of bubonic plague by fleas carried out successfully by Simond in 1898. This terrible disease, which from time to time has ravaged the Old World in epidemic form, is supposed to have caused the death of 25,000,000 people on the Continent of Europe in the fourteenth century. And in modern times it has raged in oriental countries, causing, for example, for many years in India, an average of nearly 1,000,000 deaths annually. The causative organism of the plague is *Bacillus pestis*, described by Kitasato, the famous Japanese investigator. The establishment of the identity of the disease with the one which occurs in rats had been made by Yersin in 1894 and Simond's transmission of the disease by

means of rat fleas was confirmed by Verjbitski in 1903 and by Liston in 1904. The British plague commission in India proved most conclusively that the rat flea is the principal means of transmission of the bubonic form of the plague. No less than eight species of fleas have been shown by various workers to be carriers of the plague bacillus, but the rat flea, known as *Xenopsylla cheopsis*, is the principal carrier in great epidemics. The Indian plague commission, finding the bacilli only in the alimentary tract of the fleas, and not in the salivary glands, concluded that the bacilli are present in the excreta of the flea and are inoculated into the human host by scratching. Experiments by Bacot and Martin, however, indicate that the plague can be transmitted by the bite of fleas when a temporary obstruction of the proventriculus of the insect causes the blood laden with bacilli to be regurgitated into the bite puncture.

This is the first of the diseases which we have mentioned in which the insect seems to be simply the mechanical carrier of the disease organism. In this case, as in many others, some of which we shall briefly mention, there is obviously no development of the disease germ in the body of the insect which is therefore not a necessary secondary host, but simply a carrier which, through its presence in great numbers, causes the inordinate spread of disease. There are a number of insect-borne diseases in which the causative organism has not yet been discovered, in which this point has not clearly been ascertained. When Reed, Carroll, and Lazear failed to find the cause of yellow fever, and yet were able to produce the disease from the blood serum which had been filtered, they were, nevertheless, of the opinion that there must be a causative organism too small to be seen by the highest power of the microscope, and which undergoes a part of its development in the body of the yellow-fever mosquito, since a certain definite period must elapse between the infection of the mosquito and the time when its bite gave the infection to a nonimmune, just as is the case with malaria where the organism and its full life history is so well known and so easily demonstrable.

But we must return to Ricketts and his second great discovery. This excellent investigator was connected with the medical department of the University of Chicago. Upon the conclusion of his work in Montana, his attention was attracted to typhus fever.

Typhus fever, a serious disease formerly prevalent under unsanitary conditions in the most civilized countries when people were crowded together in camps, hospitals, or jails and which, in fact, a hundred years and more ago was known as "jail fever" in England—the disease which nearly killed the "Vicar of Wakefield" in his life of many tribulations—while practically nonexistent in the United States for many years, was still rife in the prisons of the principal

cities of Mexico. Therefore Ricketts and his colleague, Wilder, went to the City of Mexico and carried on their experiments which resulted in the establishment of the fact that typhus is communicated by the body louse, the results being published in 1910. The Frenchmen, Nicolle, Comte, and Conseil, working in Tunis, had reached similar results the year previously, and the discovery was confirmed soon after by Anderson and Goldberger of the United States Public Health Service.

The causative organism of typhus is still an undecided question. Several different microorganisms have been found both in typhus patients and in lice, but that anyone of them is the actual cause of the disease is still disputed. That the disease is transmitted by the bites of lice is now thoroughly accepted, but with the microorganism still in doubt the question of its partial development in the bodies of the lice is also still in doubt. Several workers have claimed that the disease is transmitted hereditarily by lice while this has been disputed by other equally competent authorities. That the absolute destruction or prevention of lice will ward off typhus is beyond doubt.

Never in the history of the world have there been such opportunities for the demonstration of the value of a prophylactic measure as the Great War afforded with this disease. The epidemic which began in Serbia in January, 1915, spread all over the country. The necessary sanitary measures with regard to cleanliness and louse destruction and prevention were unknown, apparently, in that country, and the majority of the native physicians were soon taken with the disease and died. The American Red Cross then stepped in, and American physicians were sent to Serbia, and although by April of 1915 people were dying at the rate of 9,000 a day, the epidemic was measurably controlled. After the Russian Armies mobilized, typhus appeared and the dread disease was more or less prevalent all along the eastern front. Russian prisoners in German detention camps spread the disease and its obvious prophylaxis was put into effect by German physicians, and the life history of the body louse was carefully studied by Haase, a competent entomologist. By strenuous efforts the disease was prevented from making inroads in the armies of the Allies, although it was impossible to keep the troops at the front free from lice; and that brings us, although chronologically out of order, to the subject of another louse-borne disease, namely, Trench Fever.

In the early part of the war a young American physician, Dr. Plotz, had been studying a fever in New York City known as Brill's Disease, and had supposedly isolated the causative organism. Symptomatically this disease is closely related to typhus fever, resembling a mild form of that malady and is louse-borne. The fever which developed among the troops in the trenches resembled the disease

studied by Plotz in New York, and American and English physicians soon decided that it also was louse-borne, and measures were at once instituted to control lice in camps and entrenchments. An enormous amount of experimentation was undertaken as to the best means of destroying lice, not only on the person but in temporarily discarded clothing—toward the close of the war with great success. Troops moving from country to country or returning from the front were fumigated and their clothing was steamed or fumigated, and all American troops returning from Europe were put through one process or the other.

Without the slightest doubt in the world, there are many species of insects which act as carriers of disease in a purely mechanical way. There are many species which are attracted to exposed foods which are also attracted to excreta, to sputa, and to other substances carrying disease germs. This fact has, however, only recently become a matter of general information. The carriage of Asiatic cholera by flies was considered most probable by a number of earlier writers, but nothing seems to have been placed on record with regard to the very certain carriage of typhoid fever by the house fly until the late nineties. Kober in a report of the Health Department of the District of Columbia on an investigation of a small epidemic of typhoid, suggested the contamination of milk by the house fly, which had previously visited the excreta of typhoid patients. The subject was brought prominently before the public during the Spanish-American war. Although the Surgeon General of the Army, Doctor Sternberg, gave careful instructions regarding the disposal of the excreta in concentration camps, his orders were not well carried out, and typhoid became epidemic at many points. A commission of Army surgeons, consisting of Doctors Reed, Shakespeare, and Vaughan was appointed and their full report indicated that under concentration camp conditions the terrible spread of typhoid was due almost entirely to the common house fly. During that brief war 80 per cent of the total deaths were caused by typhoid. From that time on the control of the house fly became a very important subject, and many volumes and hundreds of pamphlets have been written giving the results of careful studies of the biology of the house fly in all its aspects and of methods of control. Later vaccination against typhoid was discovered and proved to be so effective that control of flies in camps became less important. The house fly is nevertheless a very dangerous species and is a very important factor in the spread of infantile diarrhœa in the summer months and in other ways is a constant menace to health. The necessity for laboratory proof of its carriage of typhoid and other diseases of the same general nature which has been insisted upon by Graham-Smith and other writers,

while scientifically sound, does not especially appeal to the writer from the practical point of view. The case is altogether too obvious.

It is so obvious, in fact, as amply to justify the general crusade against the house fly that began in this country about 1908 or 1909. Boards of health, both State and local, women's clubs, civic bodies, including the American Civic Association, and very many newspapers have pushed the campaign against the house fly with great vigor. The destruction of the house fly has been taught in the schools and prizes have been awarded to the child killing the greatest number of flies. It should be noted that a few members of the Society for the Prevention of Cruelty to Animals have objected to such teachings; but then there are people who are opposed to vaccination against smallpox and still others who object to well-planned vivisection. While this tremendous crusade is doing a great deal of good educationally, a lot of energy is being misdirected in a way. Crushing a few hundred or a few thousand or a few hundreds of thousands of flies with a paddle will do little good if their breeding places are left undisturbed.

We have now described briefly many of the principal discoveries of the relation of certain insects to certain diseases. Very many more discoveries have been made and doubtless very many more are yet to be made, and many trained workers are investigating many sanitary problems with the idea of possible insect carriage constantly in mind. Some poor guesses have been made on insufficient grounds, which have been widely heralded before thorough laboratory investigation and transmission experiments, but all plausible guesses must be carefully considered, and the men trained in investigation work of this kind are rapidly increasing in number. Already Pierce has tabulated in his recent work on Sanitary Entomology more than two hundred diseases that have been shown to be carried by insects, and the bibliographical journals and reviews devoted to such subjects announce new discoveries almost every month.

Most of the important discoveries have been made by pathologists, bacteriologists, and protozoologists, or by a class of workers calling themselves by the general term "parasitologists." But transmission of a disease by an insect or a group of insects once established, the trained entomologist comes in, gives his knowledge of the insect vector, and investigates every phase of its biology and behavior. An admirable estimate of what medical entomology to-day means or should mean is given by Colonel Alcock, Assistant Director of the Tropical Diseases Bureau, of London, himself an investigator of note, in the following words:

Medical entomology, too, during the last decade has become more critical and more formal. We are not now suddenly afraid of an insect merely because it has been caught in the act of sucking blood; nor even when dealing with an

arthropod of unquestioned pathogenic significance do we now think that we have done with it once for all by a command that its breeding places shall be blotted out, or its natural enemies be let loose upon it. The business of medical entomology, as now understood, is, in the case of any species convicted on pathological evidence of being a standing danger to the public health, to unriddle its biology in every detail, and to investigate all the varying circumstances that influence its acquisition and retention of pathogenic capacity. The biological inquest must comprehend every stage of the creature's existence, from the egg to the engendering adult, and must include not only its affinities and its structure, but also its bionomy and its relations to environment. The bionomic inquiry must embrace the geographical distribution and seasonal incidence; the habits and the hours of activity; the powers and range of locomotion and the propensity to spread; the food preferences, the meteorological influences, and power of resisting vicissitudes of season and climate; the sexual instincts and fecundity; the mode of reproduction, breeding places and seasons, and the provision for larvæ; and the duration of life in every stage of development. If it be not a specific parasite, the bionomic investigation must also include the relations of the species to its environment, organic and inorganic, such as the physiographical and hydrographical features of the habitat, natural shelters, help givers, parasites, enemies and rivals. An excellent example of the range of the inquiry is furnished by Swynnerton's "Examination of the Tse-tse Problem," published in the *Bulletin of Entomological Research* for March, 1921. (See p. 22.) With the accumulation of exact information on all these points and the rational inferences drawn from it, medical entomology claims to be a science of practical application in preventive medicine—in short, a branch of Hygiene, and a branch which, although it finds its fullest and most constant application in those tropical countries where sanitary arrangements are still crude and imperfect, can not in the mutability of human affairs be neglected in any country. (*Tropical Diseases Bulletin*, vol. 18, No. 1, 1921, pp. 1-2.)

In this article we have considered in a far too summary way a dozen of the great discoveries in medical entomology, practically all of them made within the space of 25 years. Even to list the others would fill far more space than can be given here. Scientific laboratories were teeming with work of this kind down to the outbreak of the Great War in 1914. For the next four years many investigations were stopped. The men working in the sleeping-sickness problem in Africa, for example, had to abandon this work and join the military forces. Men from the laboratories in all the countries at war were sent to the front or to concentration camps to help in the care of the health of the troops. Many a promising investigator was killed. Printing facilities and postal facilities were so hampered that there was almost no news of the progress of investigations sent out from one country to another as in times of peace. None of the scientific men of the allied nations knew for several years what was being done by the trained investigators of the central powers. Nevertheless, the war gave a tremendous impetus to the study of medical entomology. Typhus in the Balkans and in Poland and Russia and in camps containing prisoners from those countries, the trench fever which soon developed alarmingly on the western front, and the spread of malaria

in nonmalarious regions of Germany, France, and even England, due to the infection of native anopheles by malaria-carrying soldiers returning from the fever-stricken fields of southeastern Europe, intensified the importance of the most careful and continued study of insect vectors of disease.

During the past 20 years the scientific world has thrown itself with ever-increasing activity into the great field opened by the initial discoveries. The greater importance of insect-borne diseases in the Tropics was immediately recognized, and England's great colonial possessions justified, and, in fact, necessitated, the founding of the great Schools of Tropical Medicine at Liverpool and London. A similar school was founded later at Hamburg by the German Government, but the loss of her tropical possessions has minimized the later work at this institution. Too much praise can hardly be given to the wonderful work done by the Oswaldo Cruz Institute at Rio de Janeiro. The corps of admirable investigators there has been increased from time to time and important discoveries have been made in the lines of medical entomology which the limited space allotted to this article prevents us from considering.

Medical entomology, however, is only a branch of tropical medicine, but it is a branch which absolutely requires the help, not only in investigation but also in teaching, of entomologists. A medical man, a trained pathologist, can hardly, after devoting years of research to other lines, become a skilled entomologist, since the field of entomology is so vast that to become skilled in any one of its many aspects requires a lifetime of work. This is coming to be realized. Not only must the taxonomy of insects engaged in the carriage of disease be critically studied, but their behavior under all possible conditions, their complete biology and ecology, their physiology, and many other things must be studied, and the man trained in so-called economic entomology is the one who must be called upon to suggest the best and most economical methods of suppressing these carriers.

Thus, there have grown up in many of our colleges and universities departments of medical entomology conducted jointly by entomologists and by medical men. At the Harvard Medical College a thoroughly competent entomologist gives instructions in medical entomology. At Cornell University, where there exists one of the strongest teaching corps of entomologists, especial instruction is given in this direction. The same may be said for the University of California, for the University of Wisconsin, and other institutions.

And excellent and comprehensive books on the subject of medical entomology have already been published, aside from numerous special books, such as those of the present writer, on mosquitoes and on the house fly, and those of the late Gordon Hewitt and Graham-Smith on

the house fly and other flies, and the excellent volume by LePrince and Orenstein on "Mosquito Control in Panama." As early as 1910, Prof. R. W. Doane, of Leland Stanford University, published a book entitled "Insects and Disease." This was followed by the excellent volume entitled "Handbook of Medical Entomology," published by Professors Riley and Johannsen, of Cornell University, in 1915; and by the excellent compendium entitled "Medical and Veterinary Entomology," by Dr. W. B. Herms, of the University of California, in the same year. Later Dr. A. C. Chandler, of the Oregon Agricultural College, published his admirable volume, "Animal Parasites and Human Disease," in 1918; an excellent volume entitled "Entomology for Medical Officers," by Lieut. Col. A. Alcock, Liverpool, 1920, and in the present year has appeared the very up-to-date volume entitled "Sanitary Entomology", edited by Dr. W. D. Pierce, formerly of the Bureau of Entomology at Washington. All of these works contain full bibliographies, and it will perhaps not be necessary to add a bibliographical list to this sketch.

A number of periodicals have also been started which are largely, and in some cases entirely, devoted to medical entomology.

The enormous and promising field is rapidly being exploited, and the more it is being worked the more obvious it becomes that an enormous fight is on between the human species and the class of insects which not only destroy his crops and damage most of his valued possessions but threaten his bodily health in a host of different ways.

The effect of these discoveries on the public health is already very apparent. Thousands upon thousands of lives have already been saved as their result. The intensity of many great scourges has been relieved. One of them, yellow fever, has measurably become a thing of the past. Gorgas's magnificent demonstration at Panama has shown that, so far as disease is concerned, the Tropics may be inhabited by the white race, and what that means for the future of the world no one can now estimate. All over the United States even, a country which is fortunately for the most part situated in the healthiest of climates, life on the average is longer and happier because of the knowledge that has been gained regarding insect-borne diseases. The American Public Health Association has borne its important part as an exploiter of these discoveries, as a publicist, as an influential apostle in the preaching of the new crusade.

In glancing through the fifty or more volumes of the publications of this society one is very greatly impressed by their high character. The whole series serves as an accurate record of the advance of preventive medicine in the United States, in Canada on the north, and in Mexico and the West Indies on the south. It is interesting to note, for example, the multitude of articles and reports on yellow fever

in the earlier volumes, these beginning with an admirable address in volume 1 by my old friend, Dr. J. M. Toner, now dead for many years. On reading this address I find many suggestive statements, suggestive in the light of later discoveries. But perhaps the most interesting article in the volumes, from the historical point of view, is the revolutionary paper read by Walter Reed in October, 1900, modestly entitled "A Note on the Etiology of Yellow Fever." Lazear had just died (September 25), and Reed, when calling upon me in passing through Washington on his way to the meeting, told me that he was making his first announcement before this association on account of its great activity in matters relative to the dread disease.

The list of investigators who have died for the public good in the course of the investigations we have been considering is already large. I have mentioned Lazear, Ricketts, McClintock, and McCray, and have shown that the deaths of Reed and Carroll occurred most prematurely shortly after their monumental discovery was announced. As a fairly complete list of these martyrs of science is given in another chapter of this volume*, they need not be repeated here.

* See footnote 1.

LAI D AND WOVE.¹

By DARD HUNTER.

[With 6 plates.]

All paper was formed in single sheets by hand before the invention of the paper-making machine. For the purpose of making hand-made paper flat molds were used on which the pulp was deposited. This was accomplished either by pouring the liquid pulp upon the mold or by dipping the mold into a vat containing pulp. Through the centuries of paper making these molds have undergone many improvements and changes which have affected the character of the paper made on them to a marked degree. However, the molds used to-day for the forming of handmade sheets are based on the original principle of mold construction. To most paper makers and printers the two terms "laid" and "wove" mean little, aside from the fact that in the former the paper shows laid and chain lines when the sheet is held to the light, and in the latter the paper appears to have been woven, without much character or individuality.

The earliest paper was formed by the Chinese some 2,000 years ago on a woven cloth stretched over a bamboo frame which constituted the original paper-making mold. It is not known whether these first molds were dipped into the vat containing pulp or whether the fibrous liquid was poured upon them. As the wet sheet of pulp could not be taken from the cloth, the sheet was allowed to dry on the mold and was then removed. In this earliest form of paper making a great many molds were necessary if much paper was to be produced, for it would have required at least a day for each sheet to dry before it could be taken from the cloth covering of the mold.

It was left for an ancient Persian of genius to conceive the idea of a mold from which the wet sheet could be taken while still moist. This was the first real step in the progress of paper making, as this enabled the paper maker to make sheets continually from the same mold. For this purpose the mold had to be made from some smooth and firm material from which the wet sheet would free itself. These molds were made by placing many pieces of split bamboo or other

¹ Reprinted by permission from *The Printing Art*, September, 1921.

vegetable filaments side by side and sewing at determined intervals with horsehair, silk, or flax. The bamboo strips, as well as the sewing, left impressions in every sheet of paper that was made on the mold. The marks that were left by the bamboo sticks were called "laid," and those impressed by the sewing stitches which held the bamboo together were known as "chain lines." This manner of mold construction was the simplest and best method that could have been used in forming a firm surface that would retain the fibers and yet let the water drain away. In early paper making the lines impressed in the sheets did not appear because of their pleasing appearance, but because they embodied at the time the best all-round way of forming a paper-making mold.

The wet pulp was taken from the bamboo molds, directly after forming, onto a piece of cloth stretched over a board. The first method of drying was to place the board, with the paper, in the sun, but later a pile of paper, each sheet interleaved with a cloth, was subjected to pressure. This was accomplished by the use of heavy stones—the stones taking the place of the screw press that was used for pressing the water from the paper in later centuries of early paper making.

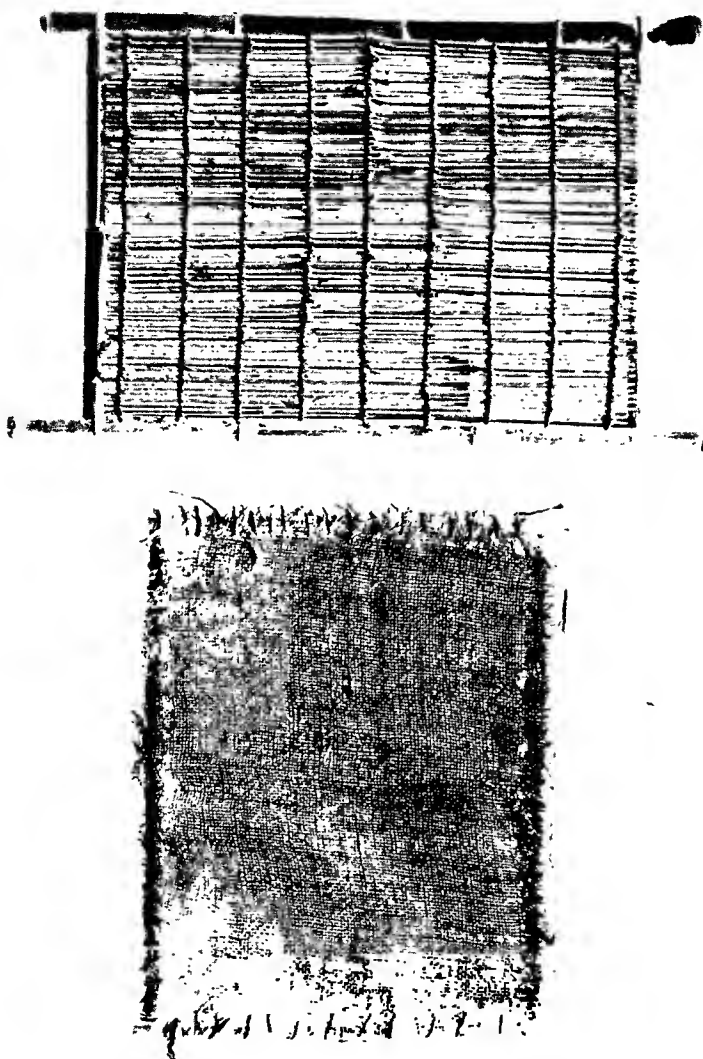
These bamboo molds of the laid pattern were employed by the Persians, and perhaps by the Chinese, a number of centuries before the introduction of paper making into Europe.

It is interesting to note that a sheet of paper made on these bamboo molds has never been discovered that had a watermark in the form of an object or design. The ancients probably did not think of this means of marking their paper; or it may have occurred to them, but as the vegetable fiber was so unwilling to twist into forms, the idea was not carried to any termination. Of course, the laid and chain lines of the mold always formed a watermark in the paper unintentionally, but the ancients did not use any emblem or symbol on the bamboo covering.

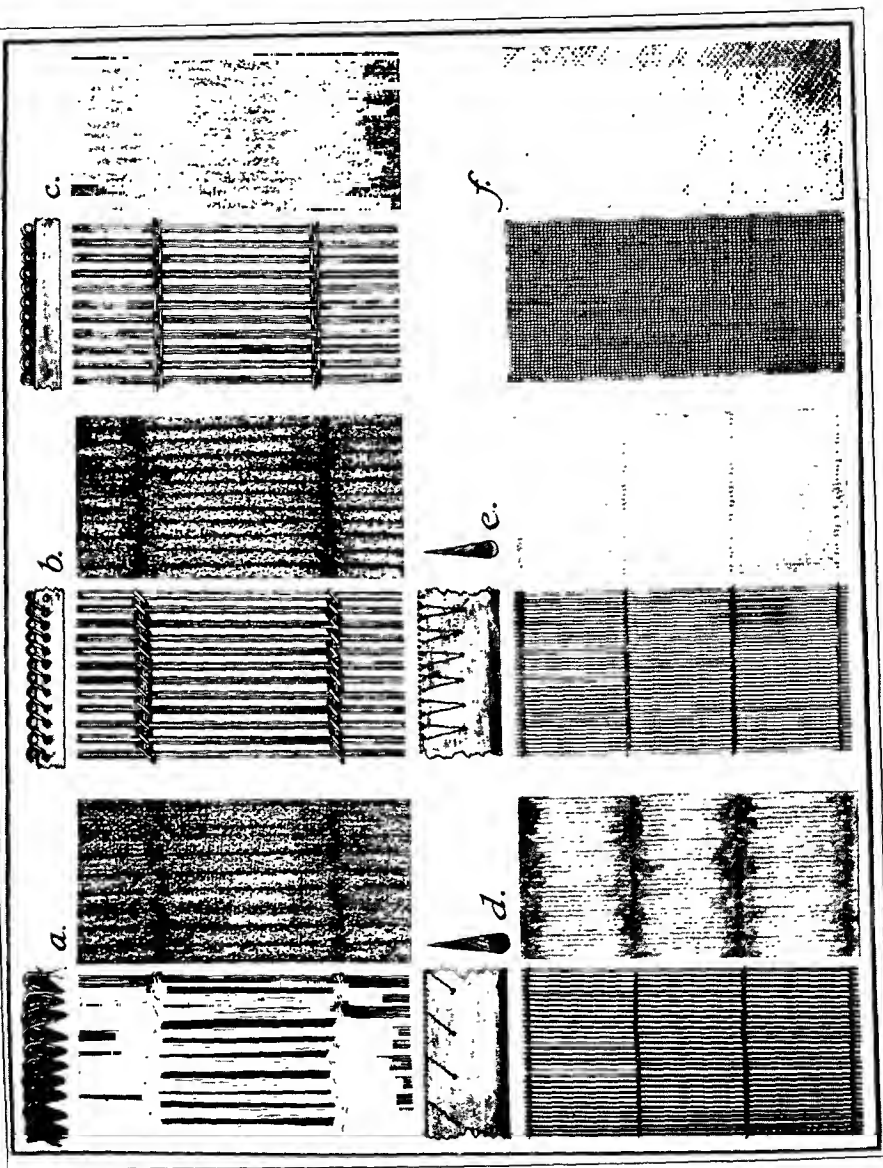
Many persons imagine that the introduction of watermarking dates from the commencement of paper making, but this is obviously a mistake.

The bamboo mold shown as an illustration in this article measures 12 by 17 inches, and the writer has made fairly good sheets of paper on it. The frame of this mold is held rigid by leather thongs at each corner. The covering, or laid lines, is composed of split bamboo filaments bound to the ribs, or supports, of the mold by flaxen threads. In plate 2, *a*, is shown a portion of a bamboo mold, also the cross section of the mold covering, and a specimen of the paper made on this type of mold.

It is not possible to determine how early these bamboo molds were used, and it is not known when wire was first introduced as a cover-



A REPRODUCTION OF THE ORIGINAL "WOVE" MOLD USED BY THE CHINESE ABOUT TWO THOUSAND YEARS AGO. THE MOLD AT THE RIGHT IS OF THE "LAID" TYPE AND WAS THE FIRST TRANSFER MOLD, BEING CONSTRUCTED OF SPLIT BAMBOO LACED WITH FLAX. THIS MOLD WAS ORIGINATED BY THE PERSIANS.



DIFFERENT TYPES OF MOLD COVERING AND THE PAPER MADE THEREON, FROM THE ORIGINAL BAMBOO LAID MOLD TO THE MODERN WOVE.

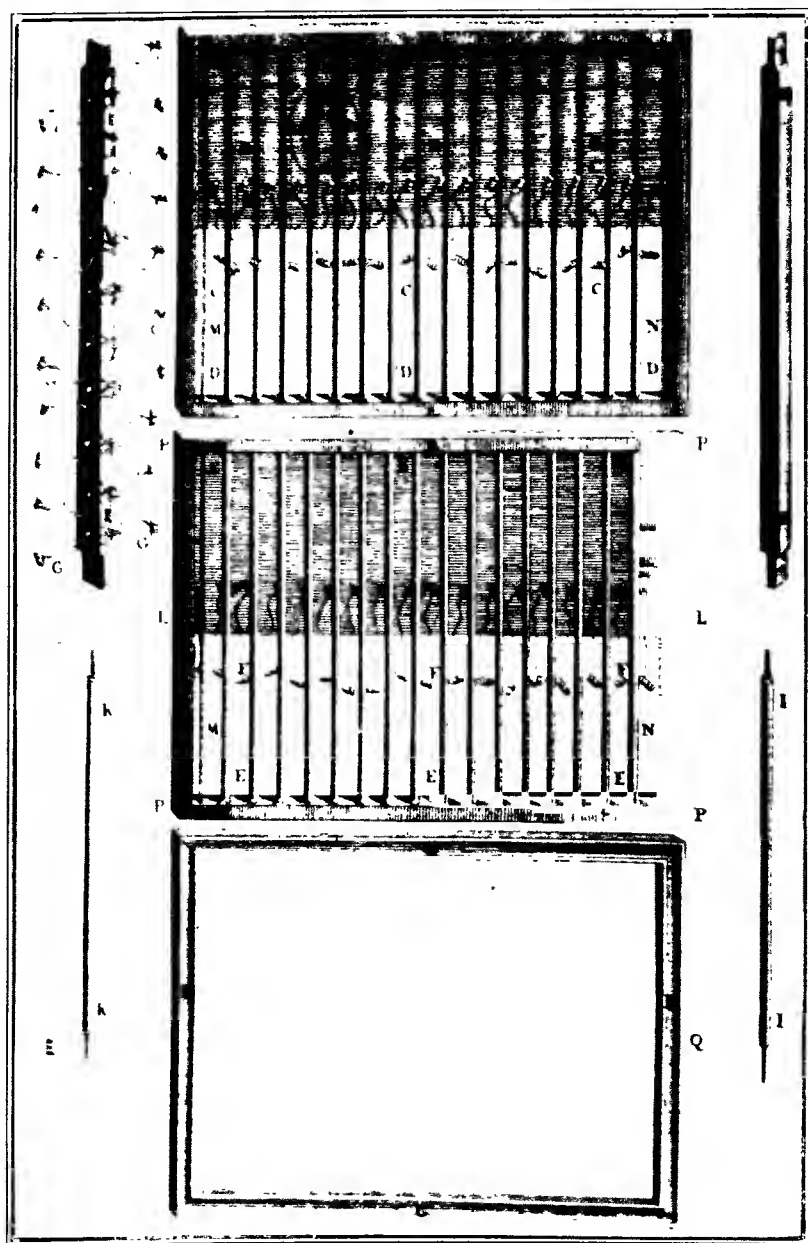
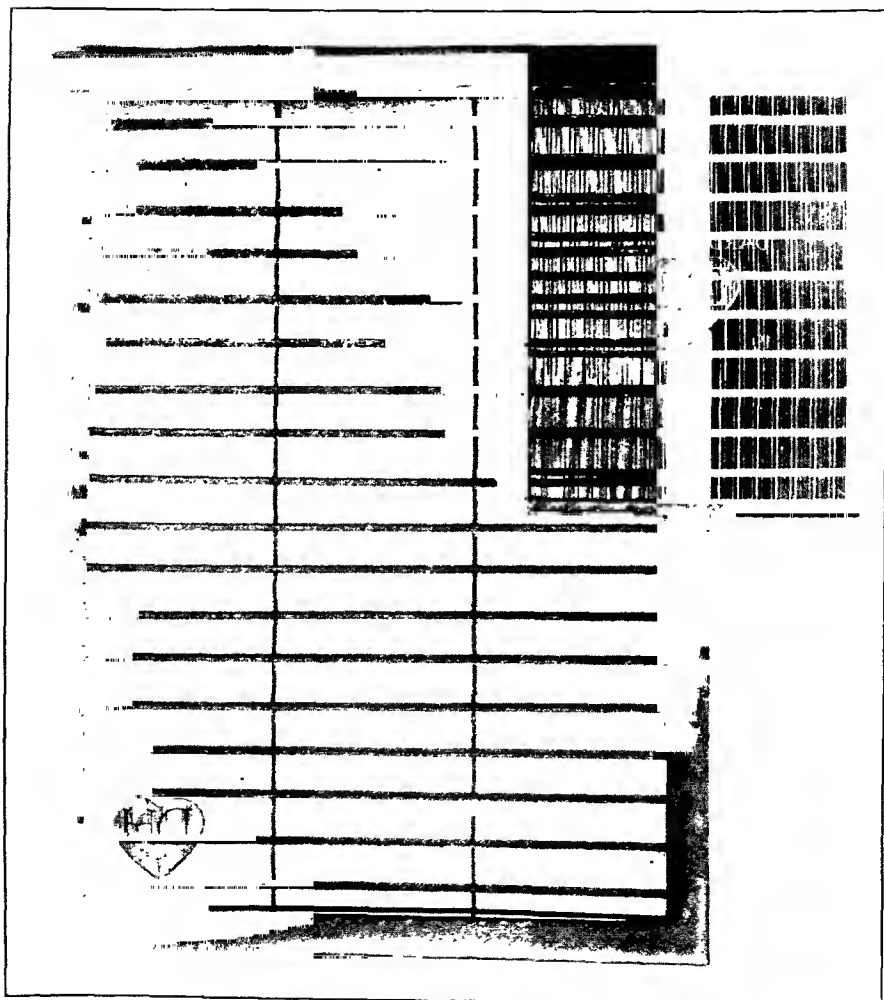


ILLUSTRATION FROM A FRENCH TEXTBOOK ON PAPER MAKING FROM 1698,
SHOWING THE CONSTRUCTION OF AN "ANTIQUE LAID" MOLD AND DECKLE.
588 3



THE LARGE MOLD, WITH DECKLE IN PLACE, IS OF MODERN MAKE BUT PATTERNED FROM ONE OF THE SEVENTEENTH CENTURY, AND IS "ANTIQUE LAID." THE SMALL MOLD, WITHOUT DECKLE, IS A "MODERN LAID" MOLD FOR FORMING NOTE PAPER.

ing for paper molds. The Moors established paper making in Europe in the tenth or eleventh century, and it is thought that metal wire replaced the natural-fiber molds in Europe a century or so later. As early as 1351 it is recorded that there were "wiresmiths and wire-drawers" in Europe. The wiresmiths would pound out the strips of metal into lengths, and the wiredrawers would draw these strips through small polished holes in hard-metal plates, repeating the process until the desired size was reached. In France a company of wiredrawers existed previous to 1583, and in London in the year 1623 there was an incorporated company of wiredrawers under the title of "The Art and Mystery of Drawing and Flattening of Wire, etc." Its motto was *Amicitiam trahit amor*: "Love draws friendship." The workers at this trade had their shops in Crooked Lane before the alterations in London Bridge.

The earliest watermark that has been discovered dates from about 1270 and was formed of wire, so we are led to believe that metal wire as a mold covering was used for some time previous to this date.

At whatever time the wire took the place of bamboo, the metal was used in precisely the same way as the vegetable filaments had been used, and the metal wire continued to make impressions of the laid and chain lines in the paper, reproducing almost in counterpart the lines left by the bamboo molds which had preceded the wire-covered molds for many centuries.

There is a great variation in the distance between the chain lines and also in the number of laid lines to the inch in papers made on either the ancient vegetable stalk molds or the metal wire molds. The paper made on the bamboo surface had coarse laid lines and the chain lines were usually widely spaced. When metal was first introduced the chain lines became somewhat closer, and the paper was more uniform in thickness, due to the wires lying more evenly upon the ribs of the molds than was possible with the uneven bamboo. In plate 2, *b* and *c*, will be seen two forms of early chain lines and the impressions they left in the paper. This type of lacing was used by early wire-mold makers, but the style shown in plate 2, *d*, was adopted almost universally later, when lighter wires came into use.

Until the middle of the eighteenth century the chain lines had been laced or wired directly to the wooden ribs of the mold, which caused the pulp to lie heavier along each side of every chain line in the sheet of paper made thereon. (These ribs and the wire in process of construction may be seen in pl. 3.) This heaviness is noticeable when the paper is held to the light. From this slight mark of distinction we are enabled to tell if a sheet of paper was made before the middle of the eighteenth century, but, of course, molds are made at the present time to imitate this characteristic. A sheet with this stamp of distinction in handmade paper is termed "antique laid," but the

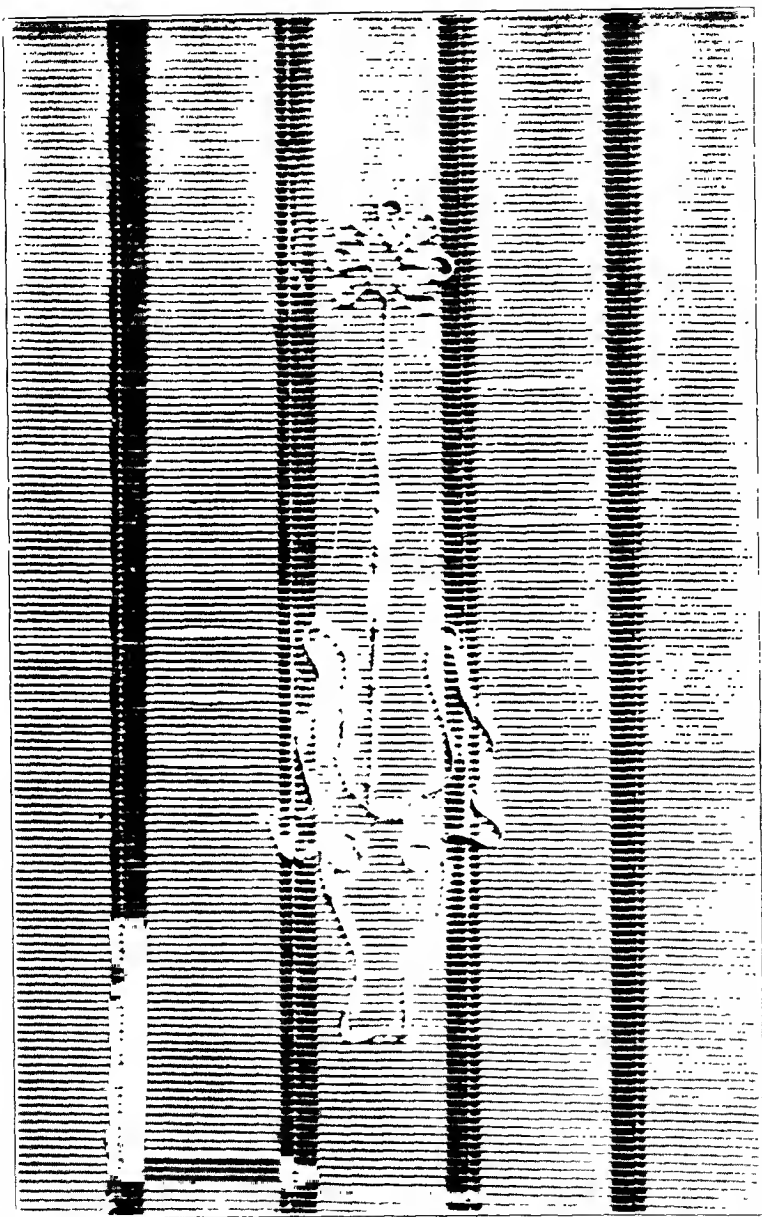
machine-made paper makers give this title to quite a different sort of paper. In plate 2, *d*, a portion of a sheet of genuine antique laid is shown, also a section of a mold on which this kind of paper is made. The absence of backing wires will be noticed in the drawing, showing a portion of a rib of this mold.

It is thought John Baskerville invented the means of eliminating these dark streaks in the paper by holding the laid covering away from the ribs of the mold by the use of wires running parallel with, and under, the laid wires. This prevented the pulp from settling at either side of the chain lines, because of the peculiar suction of the wedged-shaped ribs as the mold was drawn from the vat which contained the pulp from which the sheets of paper were made. The effect on the paper of these under wires is shown in plate 2, *e*, and also a section of a mold on which this paper is formed. In plate 4 the large mold is for making antique laid paper, while the small one is for making modern laid. The backing wires are quite apparent in the small mold, running about 7 to the inch, while the top, or laid, covering will average about 22 wires to the inch. Of course, only the top covering is visible in the finished sheet of paper. It will also be noticed that in the antique laid mold the wires are uneven to some extent, while in the modern laid the lines are in perfect unison. In plate 5 is shown a section of an antique laid mold dating from about 1760.

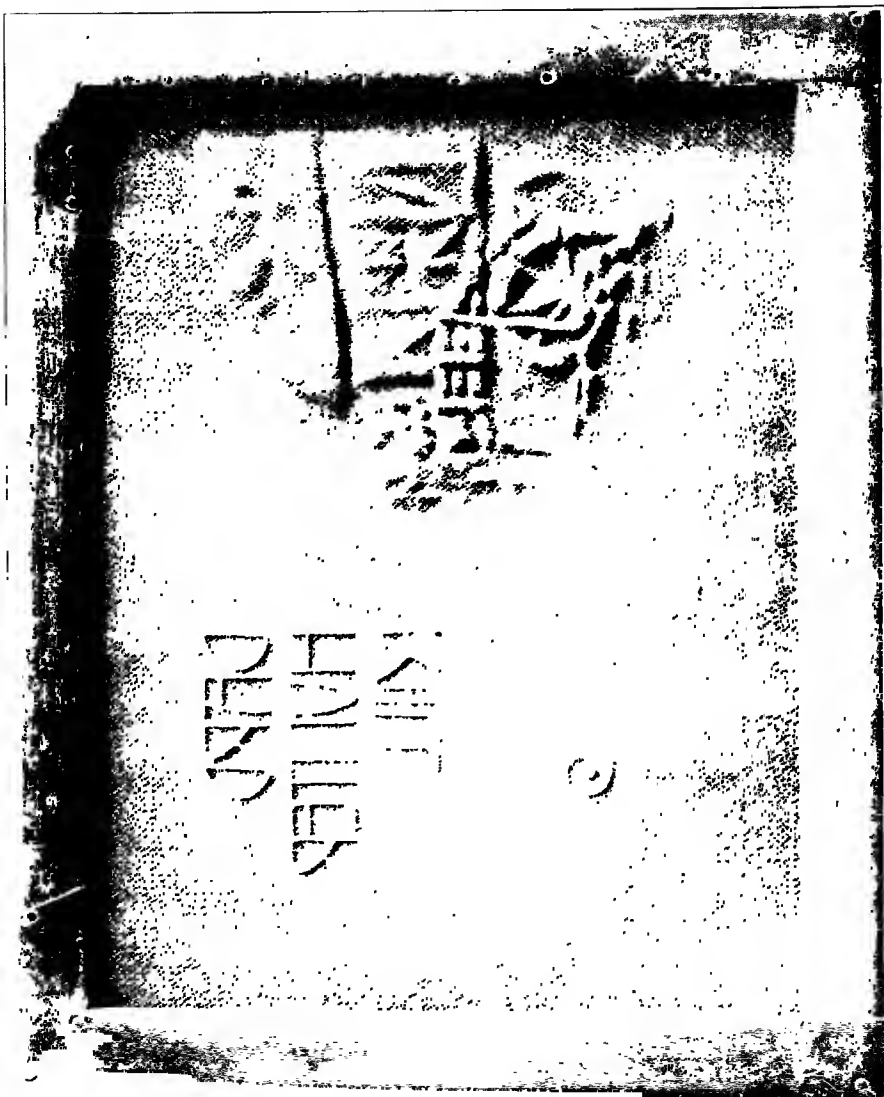
The wove mold covering was also originated by John Baskerville, and the date given for this invention is 1750. Baskerville was a printer of Birmingham, England, and he wished a smooth paper on which to print his books. The wove, or vellum, mold covering was made of fine screening, and received its name because it was woven like cloth. John Baskerville had been in the japanning and metal-working trade before becoming a printer, and he naturally was familiar with this material, as screening had been used in England for other purposes a number of years before it was put to use as a mold covering. A section of a wove mold and the impression it leaves in the sheet of paper is shown in plate 2, *f*, and in plate 6 a modern triple-wove mold for producing a light-and-shade watermark.

The first book printed on wove paper was Baskerville's edition of "Publii Virgilii Maronis Bucolica, Georgica, et Æneis," which was published in Birmingham in 1757. He printed another edition of Virgil in 1771 under the earlier date of 1757.² It is the first printing of the 1757 edition that is of interest on account of the paper.

² In the first edition, among other peculiarities, the tenth and eleventh Books of the Æneid are headed, "Liber Decimus Æneidos" and "Liber Undecimus Æneidos," while in the 1771 edition they appear uniform with the other titles, "Æneidos Liber Decimus," "Æneidos Liber Undecimus."



SECTION OF AN "ANTIQUE LAID" MOLD FROM ABOUT 1760; THE WATERMARK OF THE BULL'S HEAD IS A HUNDRED YEARS EARLIER.



MOLD FOR PRODUCING A LIGHT-AND-SHADE WATERMARKED PAPER. THIS IS A TRIPLE-WOVE WIRE COVERING.

However, not all of this edition was printed on the newly invented wove paper, as Reed³ says, “* * * of the two copies in the possession of Mr. S. Timmins, one is printed on very fine banknote (wove) paper and the other, more heavily, on coarse brown paper.” Shenstone⁴ says of this Virgil, “My neighbor, Baskerville, at the close of this month (March, 1757) publishes his fine edition of Virgil; it will for type and *paper* be a perfect curiosity.”

It was wove paper that Benjamin Franklin exhibited in Paris in 1777 or 1778. This novel paper created such a favorable impression with the paper makers and printers of France that molds were procured from England, by way of Holland, for producing the same kind of paper that the English were making. Franklin wrote⁵ a short article, which was published in 1793, on this newly discovered mold covering that was creating such a sensation.

As John Baskerville figured so prominently in the evolution of paper making, a short sketch of his life will not be out of the way. He was born in Wolverley, in Worcestershire, England, in 1706. In the year 1725 he kept a writing school at Birmingham, and in 1745 entered the japanning business; there he developed a liking for things of a mechanical nature. Baskerville later started in the printing trade while still occupied with japanning. For his types he cut his own punches and did much to elevate type design in England. The books that he printed are known for their neatness, brilliance of ink, and the smoothness of the wove paper. This he accomplished by placing each sheet as it came from the press, while the paper was still damp and the ink undried, between hot polished plates of copper and giving them a pressing. The first paper he used came from Holland, but it is stated that later he established his own paper mill. After the death of Baskerville, on January 8, 1775, his widow continued the printing business, but she issued but two books. However, she continued the type foundry until 1777. Many efforts were then made to sell the punches, matrices, and types in England, but to no avail. The complete outfit was finally purchased in 1779 by the celebrated M. de Beaumarchais, of France, for the sum of £3,700. This gentleman was a scholar of note, and he set up one of the finest printing establishments on the Continent. He reestablished three paper mills in the Vosges about 15 miles from Kehl, where his printing enterprise was located. The best paper makers that could be obtained from Holland were employed, and his paper was unequalled at the time.

³ Talbot Baines Reed, “A History of Old English Letter Foundries,” etc., p. 271, 4to, London, 1887.

⁴ Shenstone’s “Letters and Works,” Letter 88, 1791.

⁵ Benjamin Franklin, “Description of the process to be observed in making large sheets of paper with a smooth surface,” (In American Philosophical Transactions, Philadelphia, 1793, vol. 3, pp. 8-10).

While there is no set rule for distinguishing the paper of one century or country from another, it is possible, by making a study of laid and chain lines and the character of the wire impressions and texture of the paper, to arrive at the approximate date. With wove paper, however, it is not easy to attach any date to the sheet, but paper of this kind was usually watermarked with a date, and as wove paper has been made only since 1750 it is too recent to excite much curiosity from a historical viewpoint.

About 1820 there was a machine invented in England, but not patented, which by means of fluted rolls imparted a ribbed appearance to wove paper. This made the paper resemble laid paper somewhat, but the imitation may be seen when the sheet is held to the light. This fluting was thought to give a pleasing appearance to typography, and a great many books were printed on it during the early nineteenth century. The vogue for this fluted paper was of short duration, however, and genuine laid paper was rarely seen in book printing until 50 years after wove paper had been introduced. William Morris selected antique laid paper for use at the Kelmscott Press, and this type of paper then came into favor with many of the private press printers. At present, for fine book printing, either antique laid or modern laid handmade paper is used, for it is considered to be more artistic than paper made on a wove mold.

The laid and chain lines in paper form a means of determining the sizes of antique books, which in many cases are wrongly catalogued as to their original dimensions. In the binding of books they were often trimmed down so that a folio became a quarto in size. Blades⁶ says, "The weapon with which the binder deals the most deadly blows to books is the 'plow,' the effect of which is to cut away the margins, placing the print in a false position relatively to the back and head, and often denuding the work of a portion of the very text."

Books are often catalogued by bibliographers by measurement instead of by the paper. If a book is printed on a once-folded sheet, it will always be a folio, no matter how much a ruthless or ignorant binder may cut it down. This is true of all the different sizes of books. The trimming was possible in old volumes, as the margins were left wide for the notes of the readers, so that a folio could be cut down several inches without interfering with the printed text. The only way to arrive at the correct size of an old book is to examine the paper on which it was printed. In the paper molds the chain lines ran the short way of the sheet and the laid lines the long way, the watermark appearing in the center of the sheet (see fig. 1). In a folio the sheet was folded in the center, through the watermark.

⁶ William Blades, "Les Livres et Leurs Ennemis," page 99, 8vo, Paris, 1883.

and the chain lines still ran up and down. No matter how the book has been trimmed, it is always possible by this means to see that it was originally a folio. In a quarto the paper is again folded, so the chain lines run across the sheet, and a section of the watermark appears in the upper left corner of the sheet. With an octavo the chain lines run up and down, as in a folio.

As the earliest paper was made on crudely formed molds covered with a loosely woven cloth, we must accept the wove sheet as the original type of paper. The laid mold came into use a few centuries later, and as it was the first kind of mold from which a sheet of paper could be taken while wet, this invention must be considered the first real step in paper making, and it was from this original Persian laid mold that the art of paper making has developed. After the laid bamboo mold came the laid wire mold—first fabricated with iron wire and in later years with brass, the material used at present for

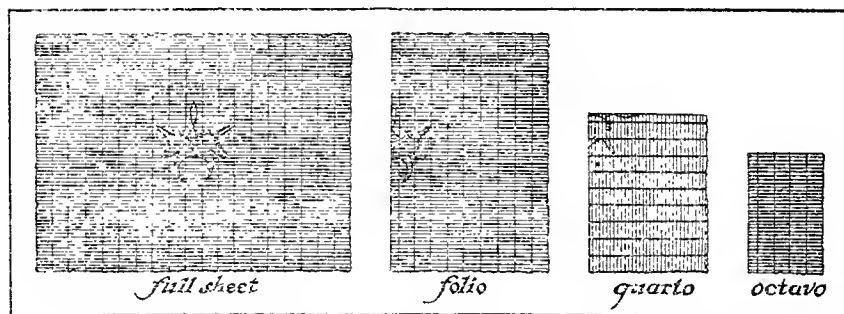


FIG. 1.—By examining the laid and chain lines in old books it is possible to detect whether a volume has been reduced in size by trimming the margins.

both laid and wove molds. Then in the eighteenth century the woven type of mold was reinvented, but instead of using the woven cloth of the Chinese, from which a sheet could not be taken while wet, woven wire was used, which furnished a firm and rigid surface. At the close of the eighteenth and the beginning of the nineteenth centuries came inventions for making paper by machine. These inventors used the original idea of the transfer, or Persian bamboo mold, only in the case of the machine the mold was continuous and formed the paper not in single sheets, as the hand mold, but in any desired length.

In modern machine-made paper the laid and chain lines are produced by means of a roller (dandy roll), which impresses these lines in the paper after the wet sheet has been formed. Therefore, machine-made paper of the laid type is nothing more than an imitation, for the laid wires are not necessary in the forming of the paper, as they are with a handmade sheet.



THE MANUFACTURE OF WHITE LEAD BY THE OLD DUTCH PROCESS (GRINDING THE CORRODED LEAD AND MIXING IT WITH LINSEED OIL). PHOTOGRAPH OF A MODEL IN THE DIVISION OF MINERAL TECHNOLOGY, UNITED STATES NATIONAL MUSEUM.

LEAD.

By CARL W. MITMAN,

Curator, Divisions of Mineral and Mechanical Technology, United States National Museum.

[With 6 plates.]

FOREWORD.

The Division of Mineral Technology, a part of the Department of Arts and Industries of the United States National Museum, is engaged in preparing exhibits designed to enhance the popular conception of the many mineral resource industries, their technology, economics and general social bearing. With the cooperation of active producers there have been obtained series of models, photographs, drawings, and raw and finished products which by their arrangement, set forth for many of the important minerals, the condition of their occurrence; the operations followed for their extraction; the processes of manufacture; the nature of the products and their adaptability to use.

Unfortunately, the opportunity of visiting the National Museum is not had by everyone and the present article is prepared, therefore, to disseminate in story form the salient features observed in the exhibit devoted to the lead industry.

GENERAL CONSIDERATIONS.

The uses of lead in the things of everyday life are almost without end. It is present in the home, in paint, in glassware, china, and pottery, and in the piano; in the church, in the pipe organ, and stained-glass windows; in the office, in the typewriter, in the window-panes, and window-sash weights; in the factory, in the bearings of all revolving machinery; in the automobile, in its engine bearings, tires, and even its license tag; in ships, airplanes, and locomotives. Without it the printing of newspapers, books, and magazines would be seriously hindered; madame would have difficulty in obtaining the right "hang" to her costume and duck hunting would be out of the question altogether.

Considering these random uses, together with the fact that there is an automobile available for every 10 inhabitants in the United

States; that every progressive community in the country has its annual "Clean-Up—Paint-Up Week"; and that even the village church has its pipe organ; the thought immediately occurs that surely there is no other metal as useful as lead. As a matter of fact, however, if the quantities annually consumed are taken as an indication, lead is outranked in usefulness by iron and steel and copper, but in diversity of utility only by iron and steel.

The benefits enjoyed by the millions of people in this country through the use of lead and its compounds are made possible through the efforts of some 60,000 individuals engaged in the lead industry, and an endeavor is made in the pages following to tell briefly of their work.

There is a leaden figure in the British Museum which was taken from the Temple of Osiris, at Abydos, one of the most ancient cities of Upper Egypt. The temple is believed to have been built prior to 3800 B. C., so that the leaden figure is approximately 5,700 years old. This is the only evidence of the early use of lead until several thousand years later, but inasmuch as lead is so closely allied in nature with silver and is a necessary factor in the production of silver, the inference may be drawn that lead was known prior to any direct evidence of the metal. Thus, the earliest known Egyptian silver is believed to be a string of beads of the period of the twelfth dynasty, 2400 B. C. There are records to show that lead was reduced from its ores by smelting prior to 2000 B. C.; lead was amongst the spoils captured by Thothmes III in 1500 B. C.; and white lead was made by corroding metallic lead with vinegar about 300 B. C. Strabo, about the beginning of the Christian era, mentions the use of high stacks to carry off lead fumes, which statement would imply that progress had been made in the metallurgy of lead and that furnaces equipped with bellows had replaced the crude hearth.

Again, there are a number of old Roman lead weights for balance scales in the National Museum at Washington dating from early in the Christian era, and the instances of the unearthing of ancient lead water pipes in various parts of Europe are numerous.

While facts to visualize still further the history of lead since the Christian era might be presented, the evidence already given indicates the gradual increase in importance of lead and therefore the gradual development of a lead industry.

At the beginning of the nineteenth century the bulk of the world's lead came from England and Spain, the industry in each of these countries having been started by the Romans; England supplied two-thirds annually and Spain one-third. Germany, Austria, Hungary, France, Russia, and the United States began to rank as pro-

ducers about 1820; Belgium entered the field in 1840; Italy in 1860; Mexico, Canada, Japan, and Greece in 1880; and Australia joined in 1888. This order in the ranks of the world's producers remained practically unchanged until 1870, when the United States displaced England for first honors, and has maintained this position ever since, producing at present over one-third of the world's supply.

For a true picture of the development of the lead industry in the United States, it is only necessary to consider the development of the country. The first settlements were made in the East, and there a lead industry was started even before that of any other metal, for protection was a necessity and lead shot was a decisive means to this end. As a result, lead ores were sought, mined, and smelted in many of the original 13 Colonies. Coincident with westward migration, lead was discovered in the Middle West and later in the Far

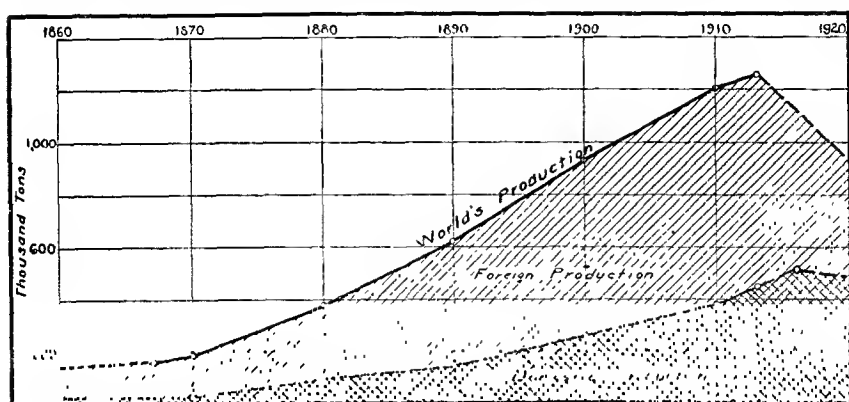


FIG. 1.—Production of lead in the United States and the rest of the world since 1860. Data from United States Geological Survey and Mineral Industry.

West and in such vast quantities that when once transportation facilities became available (about 1870) the deposits of the East, except those of Virginia, were abandoned. The story is visualized graphically in figure 2.

The outstanding feature of this growth is that it is essentially the result of domestic cultivation. There was a time between 1840 and 1850 when the demand for lead was less than the production and the excess of lead was exported; again during the restless times preceding and following the Civil War the demand exceeded the production so that lead had to be imported; and finally, to meet the demands of the Allies during the World War, the production of lead increased, even above the abnormal domestic demand, and this excess was exported. But, other than this, the lead output of the United States is used at home. As a matter of fact, the periods of home consumption and exporting of lead, as shown in figure 3, rep-

resent very closely the general growth of most of the metal industries in this country, date for date, and period for period.

LEAD ORES: TYPES AND DISTRIBUTION.

The mineral galena, a compound of lead and sulphur, is the important constituent of the majority of lead ores. It occurs in groups of cubical crystals which are "as heavy as lead" and whose faces have the appearance both in color and luster of highly polished steel. Some lead is derived from ores containing the minerals cerussite and anglesite, formed by the oxidation of galena. They, too, are "as heavy as lead" but are not metallic in appearance.

When these minerals occur concentrated in rock in quantities sufficient to make the extraction of their lead content profitable, they

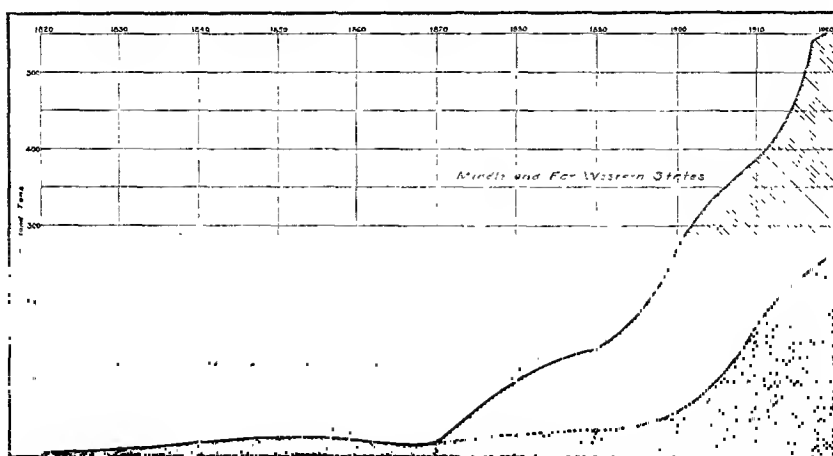


FIG. 2.—Development of the lead industry in the United States. Data from United States Geological Survey.

constitute true lead ores. In the whole of the United States there is only one section where such ores are found and mined, namely, southeastern Missouri, mainly within St. Francis, Washington, and Madison Counties. A more widespread mode of occurrence of the lead minerals is that in which they are mechanically combined with the minerals of other metals, and while the extraction of the lead alone in such ores would not be profitable, the extraction of all the metals in the combination is profitable, one metal aiding another.

Quite a number of such mineral associations of lead and other metals exist, but four only may be said to constitute the major sources from which the country's lead supply is derived. They are found and exploited in many of the Rocky Mountain States and yield approximately two-thirds of the lead used annually, while the true lead ores of southeastern Missouri yield one-third. In summary,

therefore, the country's lead supply may be considered as being obtained from five kinds of ores, as listed in the accompanying table, while the mining districts exploiting them are scattered in many of the States west of the Mississippi River, as noted in the map (fig. 4).

Sources of lead.

Type of ore.	Lead minerals.	Other metals included.	Chief mining district.	Per cent of total production.
"True lead".....	Galena.....	Silver (trace).....	Southeastern Missouri.	32
Silver-lead.....	do.....	Silver.....	Idaho.....	45
Do.....	Galena, cerusite.....	Zinc, silver.....	Colorado and Utah.....	11
Zinc.....	do.....	Zinc, silver (trace).....	Southwestern Missouri.....	7
Mixed metals.....	Galena.....	Gold, silver, copper, zinc	Scattered in Arizona, Nevada, Montana, etc.	5

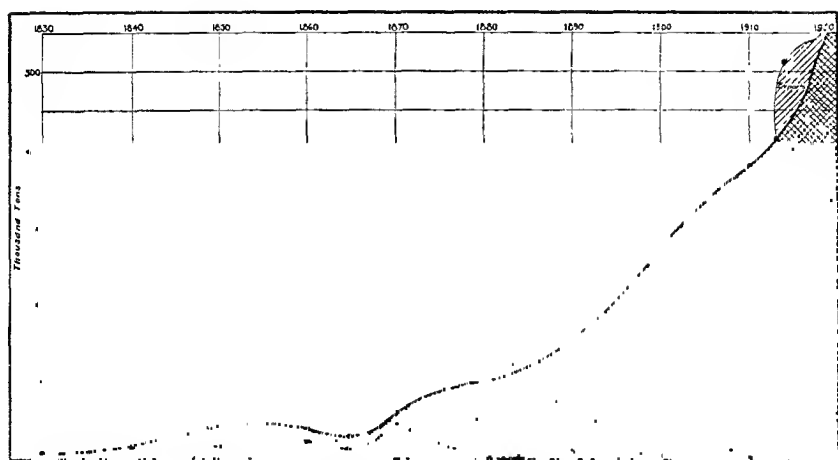


FIG. 3.—Growth of the lead industry in the United States. Data from Mineral Industry and United States Geological Survey.

The presence of silver in every type of ore is due to the fact that practically all galena contains silver in chemical combination with the lead. Zinc, copper, and gold, on the other hand, are derived from minerals physically combined with galena. In addition to the lead obtained direct from ores, a considerable amount is recovered annually from secondary sources, such as scrap pipe, cable coverings, storage-battery lead, and sheet lead. Remelted scrap often contains impurities, such as antimony and tin, and is not ordinarily substituted for lead direct from ores unless its origin and uniformity is proven.

A striking illustration of certain stages of development experienced by the lead industry which are constantly recurring, is con-

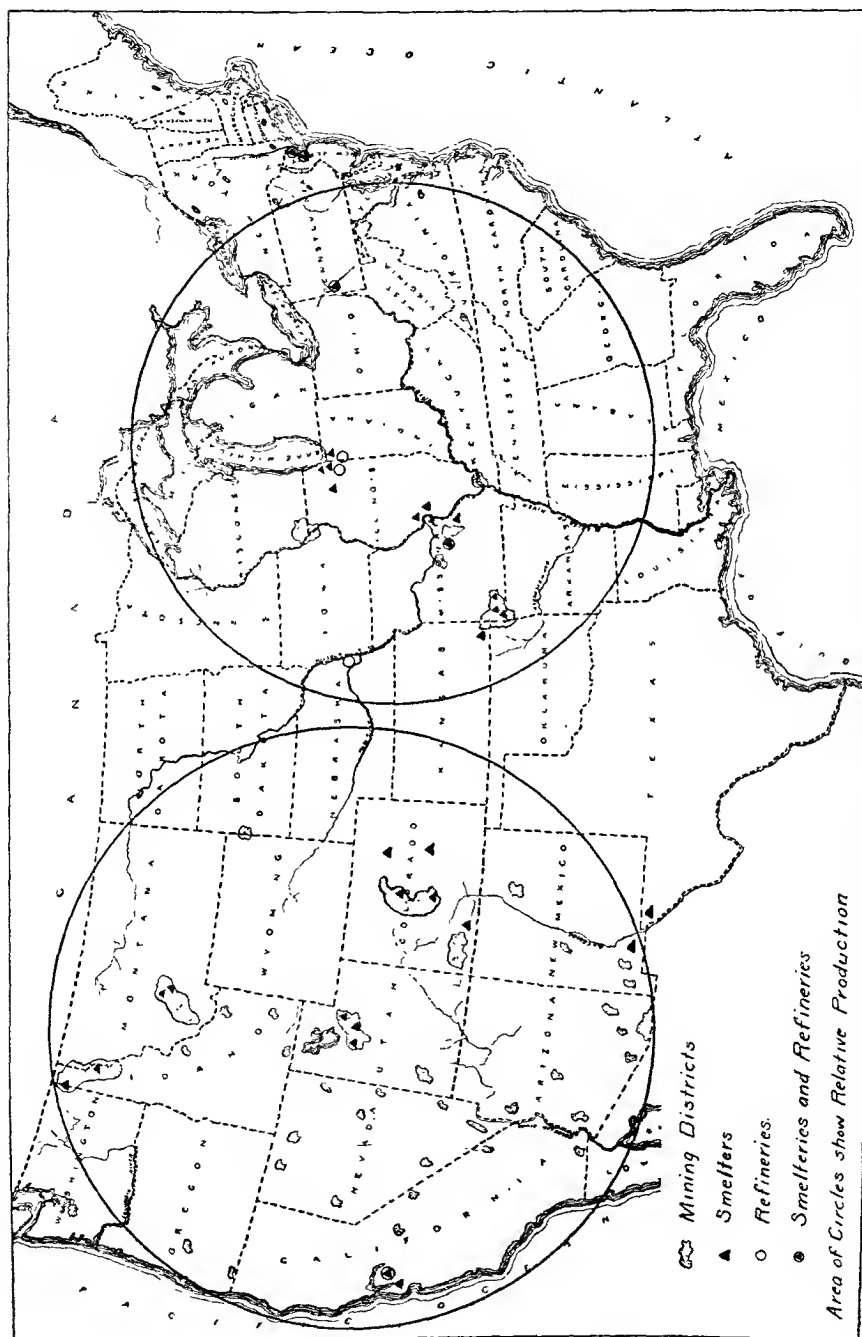


FIG. 4.—Distribution of the lead resources of the United States, together with the lead smelters and refineries. Data from United States Geological Survey.

tained in the above table but probably even more clearly portrayed in the graph (fig. 5). They are the transitions brought about by the changing character of the ores. Prior to 1870 lead was derived from simple ores by a comparatively simple procedure, but after that date, which marks the connecting of the East and West by rail, the field of industrial opportunity was greatly enlarged, bringing about increased demands, and subsequently the realization of the limits of the ores then being used to meet the requirements. The result was that ores wholly different in character had to be used, and the industry, therefore, was compelled to progress from simple direct methods to complex ones, requiring, more and more, the highest order of industrial coordination. As a matter of fact, few industries in the United States have escaped this transition, for it is a characteristic of industrial progress and runs parallel with an advancing civilization.

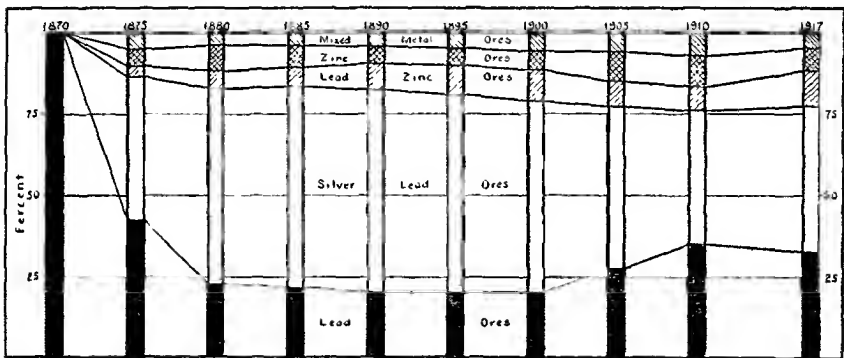


FIG. 5.—Changing composition of the lead resources. Data from United States Geological Survey.

LEAD ORES: OCCURRENCE, MINING, AND TREATMENT.

Although no two deposits of the same type of lead ores occur exactly alike, there is a similarity among types found in the same general sections of country. Thus, in the Mississippi Valley where the land is generally flat, the ore bodies occur in horizontal or gently rolling rock strata, but in the Rocky Mountains they may occur in all sorts of positions of rock strata from horizontal to vertical. In the southeastern Missouri district the ore bodies lie in pitching troughs and in a number of different ways: (1) Disseminations in limestone and shale, (2) horizontal sheets along bedding planes, (3) filling the walls of joints, and (4) in cavities in the country rock. The first is of the greatest importance commercially. They are found from 150 to 800 feet beneath the surface and vary in size from 5 to 100 feet in thickness; 25 to 500 feet in width, and have been traced for upwards of 2 miles. Being of such enormous extent and con-

tained in strong rock strata, the ores can be and are mined in great rooms or "stopes" where, by the aid of mechanical devices both in breaking down the ore and in handling it, large tonnages are obtained. These large scale mining operations are an economic necessity, for the reason that hardly more than 70 pounds of lead are obtained from each 2,000 pounds of ore brought to the surface, so that only by extensive and efficient mining operations can the low price of lead be maintained.

The formation of these vast ore bodies required millions of years for the accomplishment. They had their beginning at a time when the greater portion of the middle section of the United States was an inland sea banked by land composed of rock formations of plutonic origin and containing galena as well as other minerals. During successive periods of erosion of these land areas by surface and underground waters in circulation, the metallic compounds resulting were carried by these waters into the sea, where they became incorporated in the sediments then forming. At a subsequent geologic period the inland sea receded southward, leaving these sediments, which were gradually consolidated into the rock masses of limestone and shales that to-day form the land areas of the central portion of the United States. The galena in these rocks was at first widely dispersed in several successive beds, but, due to the activities, in part of waters descending, and in part ascending through them, the galena was again taken into solution and was moved about in the fractures in the rock beds through which these waters traveled. Finally, however, on coming in contact with reducing agents, such as organic matter in the limestone or shale, the galena was precipitated from the solutions resulting in the accumulation of the masses of ore as they are found to-day.

The lead deposits of the Rocky Mountain States occur in limestones, sandstones, shales, and also in rock formations of volcanic origin, all of which, due to orogenic activity, have been twisted, folded, cracked, and faulted. The ore bodies are irregular in dimensions and extent and, literally speaking, one day will find the miners picking in ore and the next day in barren rock. The combination of these conditions requires, first, extensive timbering of the mine to prevent the falling and sliding of rock both when in the ore and when in barren rock, and, second, conducting mining operations on a small scale with a preponderance of hand labor. The cost of this method of mining is considerably higher than that in the Mississippi Valley and would be reflected in the price of lead except for the fact that the presence of silver, copper, or zinc in these ores enhances their value to such an extent that the lead can be marketed in competition with that from other sources.

As to the origin of these various deposits, they are all associated directly with plutonic activity, hot waters originating deep down in the earth and holding lead, silver, copper, gold, and zinc in solution, ascending and depositing their metallic burden as they encountered the right conditions of temperature, pressure, and reducing agencies. The Coeur d'Alene district of Idaho, for instance, is an area composed originally of metamorphosed sandstones and shales of one of the oldest geologic periods, which have been intruded by masses of molten rock of varying compositions and then solidified. Accompanying these intrusions were water solutions of subterranean origin carrying metallic compounds from which the metals were later precipitated, forming fillings in open spaces but largely replacing the surrounding rocks along zones of fissuring or shearing. The deposits, which have a vertical range of 4,000 feet, were probably formed beneath several thousand feet of overburden, which has since been removed by erosion, bringing the ore bodies to light.

ORE DRESSING OR CONCENTRATION.

The mined ore, no matter what its origin, on being brought to the surface, is treated to separate the dirt from the valuable minerals and further to separate the several minerals from each other. This treatment is called ore dressing; the structure in which it is conducted being called the mill. The treatment is almost wholly mechanical and involves "crushing" to unlock the waste and valuable portions of the ore; "screening" to grade the broken ore; and "concentrating" to separate the valuable from the waste portions of ore. Mills constitute the surface improvement of a mine, located there for the reason that the lead content in a ton of ore is very small and very heavy, and to transport such heavy ores just as they are taken from the mines, directly to the smelters, would involve an expense greater than the value of the ore would warrant. By first eliminating the waste portions, however, and concentrating the valuable minerals to such a degree that at least one-half the weight represents recoverable lead, shipping to the smelters becomes feasible.

SMEETING AND REFINING.

Smelting is the name applied to the practice of extracting a metal from its ore by the aid of a flux and heat. Were the ores of lead absolutely pure, smelting would be a simple operation, but the presence of impurities makes it an intricate and highly specialized art. From the smelters' point of view there are two classes of lead ores in the United States—high-grade nonsilver ores, such as those of southeastern Missouri, and low-grade ores carrying silver, zinc, gold, and copper in addition to lead, such as are found elsewhere. The

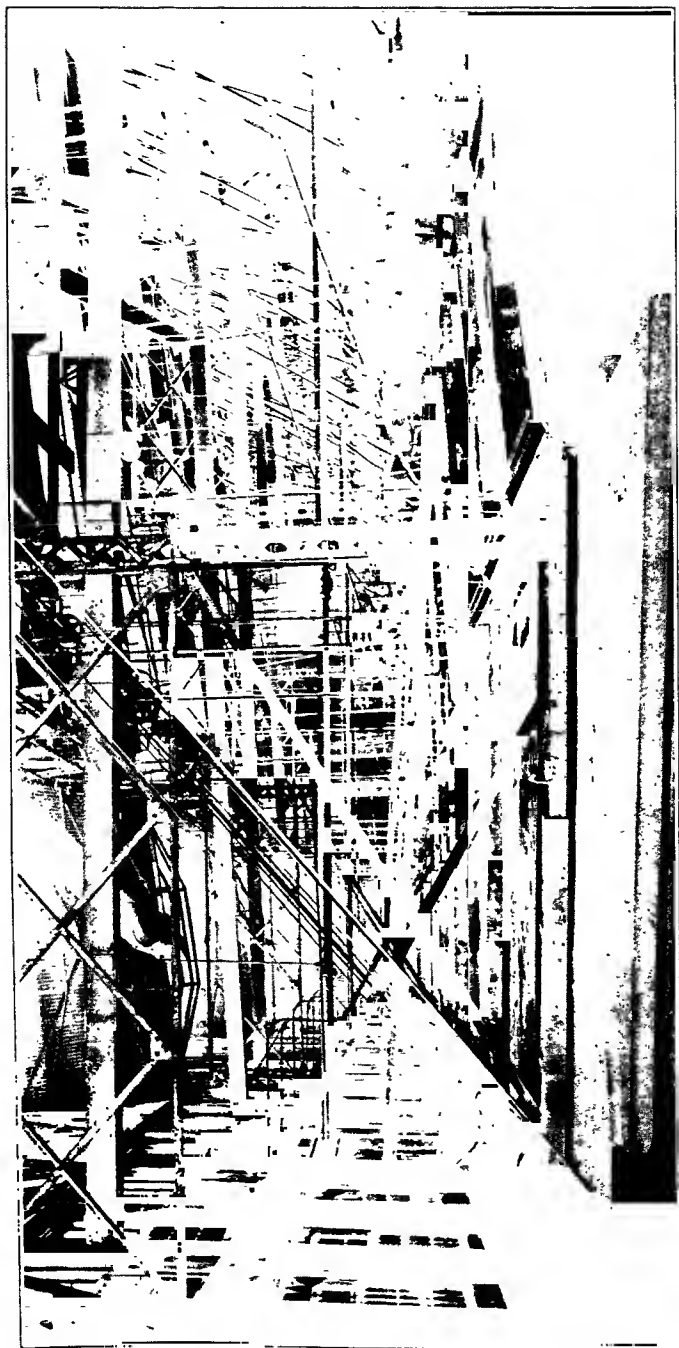
former are the nearest approach to pure ores and the smelting of them involves roasting, that is, heating at a high temperature in the presence of air, sufficient to oxidize and drive off the sulphur from the galena and free a great proportion of the lead. The furnace used for smelting this class of ores is known as the Scotch hearth and while in the early days, when the lead industry centered entirely in Missouri, it was the chief form of smelting furnace, its use to-day is greatly restricted, due to the increasing complexity of the ores and their decreasing purity.

The ores of the second class, comprising almost two-thirds of the lead ores mined, have other valuable minerals intimately associated with them as well as nonmetallic compounds which are even more refractory, so that heating to a very high temperature and in the presence of a flux is required to separate the lead from the associated substances. Blast furnaces are used for smelting this class of ores and the flux generally used is a mixture of sand, iron ore, and limestone. The nonmetallic substances in the ore have a greater affinity for the silica in the sand than they have for the lead so that in the course of smelting new relationships are formed, the lead is freed and flows out of the furnace pure, except for the other metals contained. These are eliminated by refining. Smelting is a delicate operation requiring an intricate manipulation of the mixture of fluxes and ores composing the furnace "charge," so that after the mixture has passed from top to bottom of the furnace all of the impurities have parted company with the valuable metals and gathered together as a "slag" while the lead and other metals have joined together as a separate body. The "slag" being lighter floats on the molten metals with the result that when the furnace is "tapped" the "slag" flows off first in one direction and the molten metals follow in another.

Silver, copper, antimony, arsenic, and bismuth are often present in lead in small yet sufficient quantities to be objectionable, and refining comprises the removal of these metals, so far as practicable. Silver and copper are eliminated by the use of zinc, the zinc being melted into the lead in a large iron pot and the mass made red hot. In this state the copper and silver combine with the zinc forming a new compound which rises to the top of the molten mass as a scum. The scum is then distilled in a retort which process eliminates the zinc and leaves a residue from which the copper and silver are recovered. Antimony, arsenic, bismuth, and the minor nonmetallic impurities are eliminated after the removal of the silver and copper by making use of the fact that, at a red heat and in the presence of air, they are oxidized and converted into new compounds which separate from the lead. The practical application of this truth is the refining process generally known as "poling," deriving its name



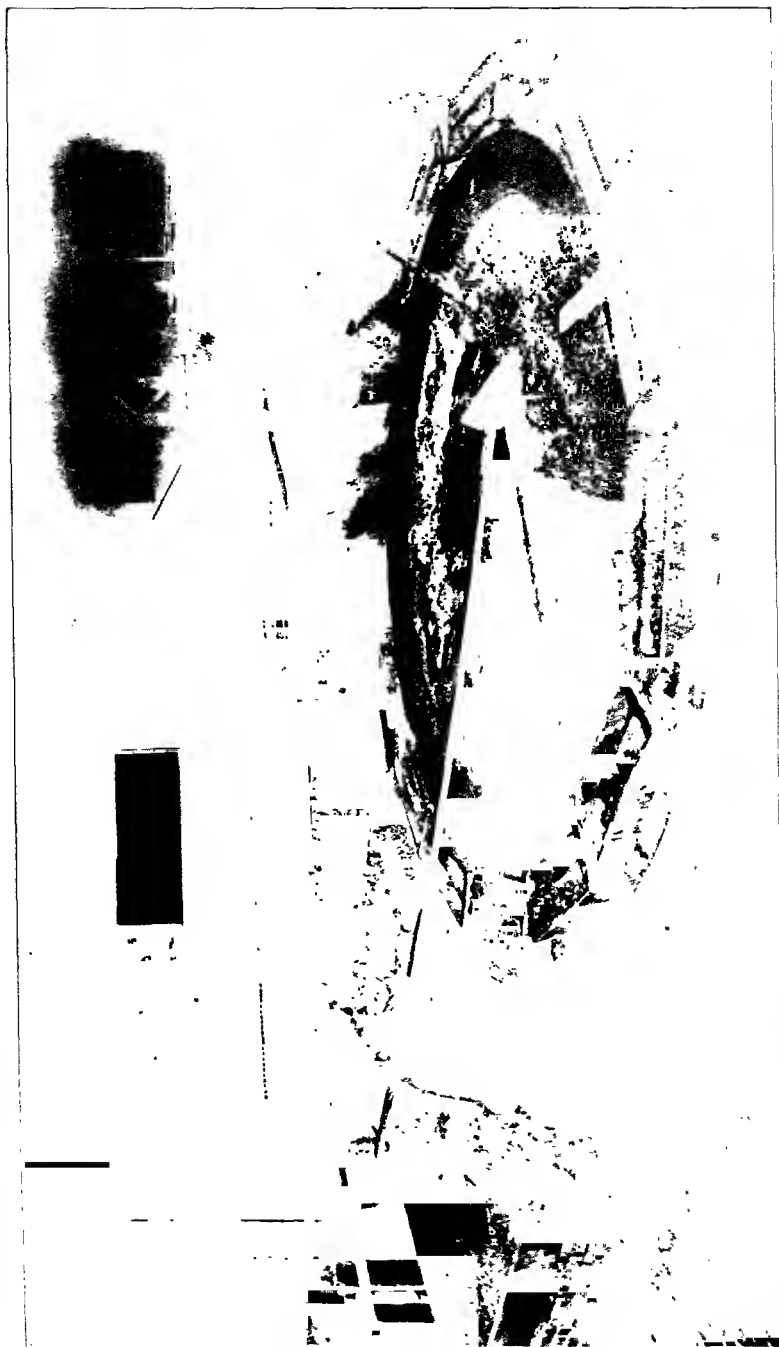
IN A LEAD MINE. MINERS ABOUT TO ASCEND. FROM A TRANSPARENCY IN THE DIVISION OF MINERAL TECHNOLOGY, UNITED STATES NATIONAL MUSEUM.



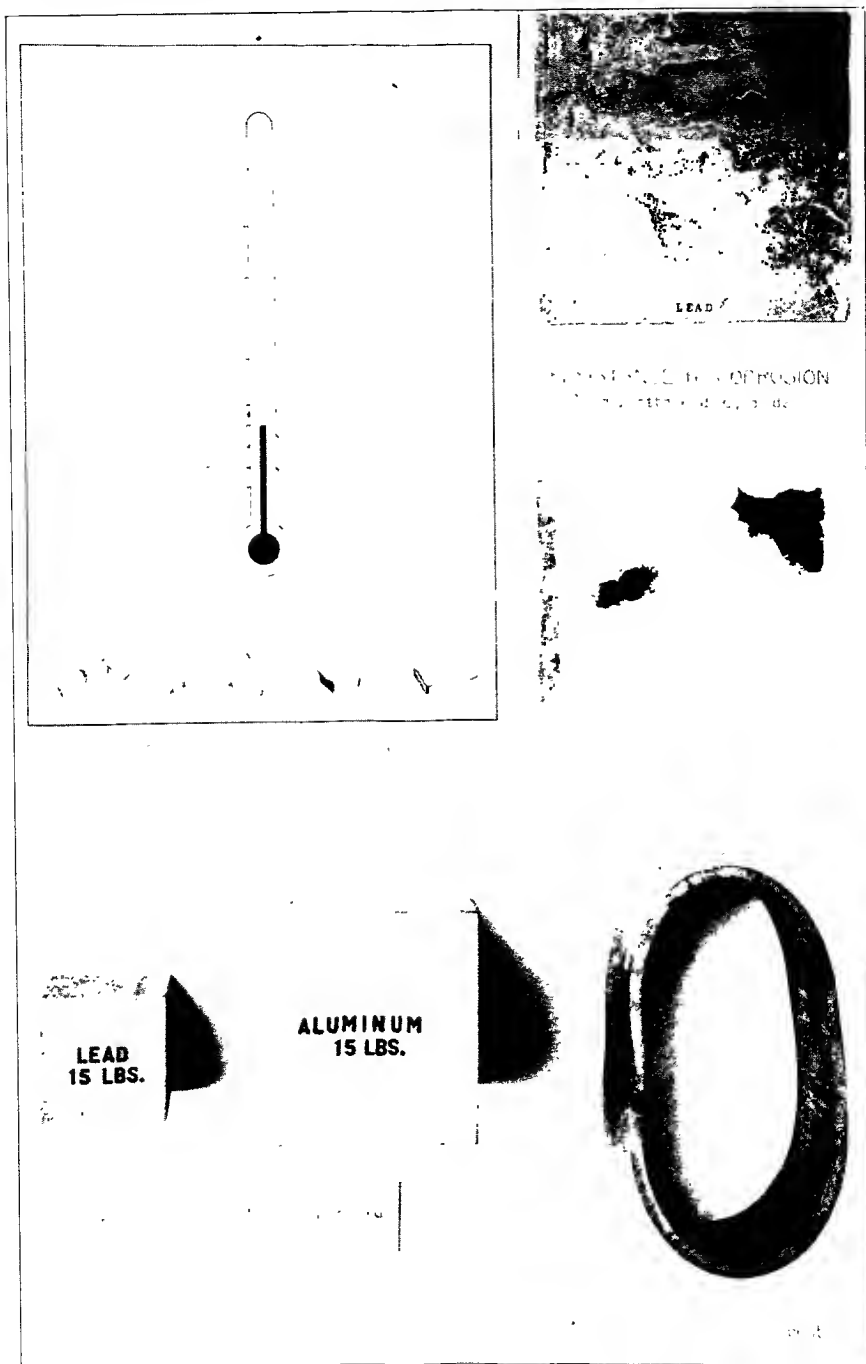
THE CONCENTRATION OF LEAD ORES. SEPARATING THE LEAD MINERALS FROM THEIR NATURAL ASSOCIATES. FROM A TRANSPARENCY IN THE DIVISION OF MINERAL TECHNOLOGY, UNITED STATES NATIONAL MUSEUM.



THE SMELTING OF LEAD ORES. THE SCOTCH HEARTH, WHERE THE LEAD IS EXTRACTED FROM THE ORE. FROM A TRANSPARENCY IN THE DIVISION OF MINERAL TECHNOLOGY, UNITED STATES NATIONAL MUSEUM.



THE REFINING OF LEAD. REMOVING SILVER BY THE AID OF ZINC. FROM A TRANSPARENCY IN THE DIVISION OF MINERAL TECHNOLOGY,
UNITED STATES NATIONAL MUSEUM.



SOME IMPORTANT PROPERTIES OF LEAD. PHOTOGRAPH OF A GROUP OF OBJECTS IN THE LEAD EXHIBIT, DIVISION OF MINERAL TECHNOLOGY, UNITED STATES NATIONAL MUSEUM.

from the fact that poles of green wood are immersed into the pot of molten metal while it is still red hot. The poles have no metallurgical function but as they burn, gases are given off which cause the molten metal to churn and boil and thus expose large fresh surfaces to the air so that it can oxidize the impurities. In their converted form the impurities rise to the top of the molten metal as a dross which is removed. The metal remaining in the pot which is almost pure lead is then poured into molds; that is, cast into bars of approximately 100 pounds each in weight, called "pigs" and stored or shipped to the markets as the case may be.

Lead smelters and refineries are distributed quite widely over the country as will be observed in the map shown on an earlier page, but with more or less concentration at industrial centers, notably San Francisco, St. Louis, Chicago, Pittsburgh, and in the vicinity of New York. The same is true of lead products manufacturing plants.

LEAD MARKETS.

Lead is the purest of the more common base metals used in commerce, the impurities rarely exceeding one-tenth of 1 per cent. But, even though almost pure, the kind and the amount of the impurities contained determine the use to which the lead may be put as will be observed in the accompanying table:

Composition and uses of American pig leads.

Name.	Composition (italic figures influential).						
	Silver.	Arsenic.	Antimony.	Bismuth.	Copper.	Iron.	Zinc.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Southeast Missouri desilverized	0.0004	Trace.	0.003	0.003	0.0003	0.0015	Trace.
Ordinary corroding or refined	0.0005	Trace.	0.005	0.05	0.0003	0.0015	Trace.
Ordinary common	0.0005	Trace.	0.01	0.03	0.0006	0.0015	Trace.
Southeast Missouri undesilverized	0.007	Trace.	0.003	0.003	0.03	0.0015	Trace.
Southwest Missouri desilverized	0.0005	Trace.	0.002	0.003	0.019	0.0015	Trace.

Name.	Composition (italic figures influential).			Resultant uses (in order of preference).
	Cobalt and nickel.	Total impurities.	Lead.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
Southeast Missouri desilverized.	None.	0.0082	99.9918	White lead and lead compounds on account of small content of silver, copper, and bismuth.
Ordinary corroding or refined.	None.	0.0576	99.9424	
Ordinary common.	None.	0.0926	99.9074	Lead compounds; but more particularly in plumbing and other uses because of large antimony content.
Southeast Missouri undesilverized.	0.008	0.0825	99.9175	Lead sheet, pipe, bar, or wire in chemical industries because of large copper content.
Southwest Missouri desilverized.	0.0018	0.0278	99.9722	Lead sheet, pipe, bar, or wire in plumbing; cable coverings, and alloys.

THE MANUFACTURE OF LEAD PRODUCTS.

An industry comes into existence as a result of the usefulness of a commodity, which usefulness, in turn, is due to the chemical and physical properties possessed by the commodity. It is logical, therefore, to review the properties and uses of lead before describing the manufacture of lead products.

PROPERTIES AND USES OF LEAD.

1. DENSITY.

This is probably the most apparent and surely the best known property of lead—a handful of lead being about as heavy as a shovelful of coal and equal in weight to two handfuls of aluminum. Because of this excessive weight in small bulk the use of lead for window-sash weights is extensive; every piano key has a lead counterweight which brings the key back to rest after being struck; and small-bore firearm and shotgun ammunition is made exclusively of lead primarily because its weight counteracts more effectively the resistance of the air.

2. HARDNESS.

In the “scratch hardness” scale of metals lead is the unit, being the most soft. It is easily marked with the finger nail and will make a mark on paper. There are no uses for lead based solely upon its hardness, but its value as a bearing metal is due in part to this property.

3. MALLEABILITY, DUCTILITY, AND ANTIFRICTIONABILITY.

Because lead is malleable and ductile it can be made easily into sheet, pipe, bar, wire, etc. Its malleability is also made use of in packing and calking. Because of its plastic nature lead in the form of pipes and sheets can readily be bent as desired.

The natural physical properties of lead are quite limited, but science has revealed the fact that by combining two or more metals the resultant product may have properties and uses distinct from those possessed by the individual metals contained in the combination. Such combinations of metals are called “alloys” and may be defined as mixtures of two or more metals which were completely dissolved or miscible at the temperature at which they were mixed. Lead is quite adaptable to such combining and the manufacture of lead alloys has greatly enlarged the field of usefulness of the metal.

Thus the perquisites for a type metal are low melting point, the taking of a sharp impression of a mold, and being sufficiently tough so as not to lose its shape and at the same time not cut the paper. Lead fulfills the first two of these requirements, but is too soft for the third. By alloying it with antimony and tin, however, the

hardness and toughness are so increased that all three requisites are met. Again, variations in the proportions of metals forming an alloy cause a change in the properties of the latter. Thus a certain mixture of lead and antimony produces type metal while another combination of these two metals with arsenic is required for lead shot.

Until recently there were recognized only two alloys of lead, i. e., alloys in which lead forms the greater portion of the mixture. These were type metal and shot metal. The scarcity of tin (extensively used, and the chief metal of many bearing metal alloys, such as Babbitt) during the war caused an intensive search to be made for a bearing metal requiring no tin. The result was the finding of an alloy fulfilling this requirement and composed of 99 per cent lead and small amounts of barium and calcium. Tests made upon this new metal by the Bureau of Standards showed that it possessed all the requisites of a good bearing metal, namely, hardness, compressive strength, low friction, heat resistance, and low cost. Its melting point is about the same as that of lead, and it can be readily rolled, drawn, extruded, and used in die cast form.

Again, the plasticity, hardness, and weight of lead have caused its use in certain alloys extensively employed for the manufacture of organ pipes; the keys of flutes, clarinets, and similar parts of other musical instruments.

4. FUSIBILITY OR MELTING POINT.

Much of the importance of lead is due to its low fusibility or ease of melting. The principal uses for lead based on this property are shown in plate 6. In addition to these uses, lead forms an important ingredient of certain metals used in the manufacture of toys, statuary, and household utensils.

5. RESISTANCE TO CORROSION.

Most metals are attacked by acids, acid vapors, and salts, but the amount of corrosion varies considerably. On lead it is less violent than on many metals, and accordingly lead is used in the form of sheet and pipe for the water connections of dwellings and office buildings (especially for carrying off waste), in chemical plants, and for covering electric cables.

6. CASTING QUALITY.

When molten lead is poured into a mold and allowed to solidify it is observed that it takes a very sharp impression of the mold, filling the most narrow as well as the widest crevices. For this reason, mainly, all printing type contains a large percentage of lead, other ingredients being added to harden it, toughen it, and increase its fusibility. This property is likewise influential, in part, in the

selection of lead alloys for the manufacture of toys, statues, and household utensils mentioned earlier.

PROPERTIES AND USES OF LEAD COMPOUNDS.

Certain members of the oxide group of chemical compounds are so unstable that a small amount of heat will cause them to separate into their constituent parts, freeing oxygen. Lead oxides belong to this group, and in the form principally of red lead, litharge, and lead peroxide, respectively, they are used in the manufacture of glass, pottery, and porcelain; in the manufacture of storage batteries, rubber, matches, and in the refining of petroleum.

Red lead is a chemical compound of two parts of lead monoxide (litharge) and one part lead peroxide. It is a brilliant scarlet red in color and is obtained in a number of grades, each grade having some particular use. The grade used as a paint pigment has the property of opacity or hiding power, and finds its most extensive use as a preserving paint for metals subject to atmospheric influences. The several other grades of red lead are used in the manufacture of glass where it is melted with the silica and other raw materials composing glass, so that its oxygen can assist in burning up the impurities in the glass; in the manufacture of varnish, where it is boiled with linseed oil in the making of varnish to promote the drying qualities; in the manufacture of storage batteries, where the red lead is made into a paste with the addition of diluted sulphuric acid and is filled into the gratings or "grids" (made of metallic lead) and allowed to dry. After the paste becomes hard, the "grids" are placed in sulphuric acid and charged by electric currents, making the positive and negative plates composing the "workings" of a storage battery.

Litharge is a chemical compound of lead and oxygen (lead monoxide) containing approximately 93 per cent of lead and 7 per cent of oxygen. It is a buff-colored substance produced both in granular and flake form. Like red lead, there are a number of grades of litharge, the uses to which the different grades are put giving rise to the names by which they are known commercially: Thus, glass-makers' litharge, color-makers' litharge, rubber-makers' litharge, varnish-makers' litharge, enamellers' litharge, potters' litharge, and accumulator litharge.

Glassmakers', varnish-makers', and accumulator litharges are used in the same way as red lead and described earlier. Rubber-makers' litharge is used as an accelerator and controller in the vulcanization of rubber. In any considerable quantity litharge can not be employed for light-colored rubber, for it tends to blacken the product. Potters' litharge is used for making a glaze on pottery, although

white lead is more extensively used for this purpose. Briefly, the process is as follows:

After the clay is molded into shape it is burned, when it becomes known as "biscuit ware." The biscuit ware is then dipped in a water pulp made of litharge (or white lead), clay, whiting, and zinc oxide, which is deposited on the surface as a thin film and when heated melts and forms a glaze. Enamelers' litharge is identical with potters' litharge, both in character and in use.

Litharge is also used by petroleum refiners. The crude petroleum is run into large tanks, where it is treated with diluted sulphuric acid. It is then washed with water to remove the acid and other soluble impurities. A solution of caustic soda in which litharge has been dissolved is agitated with the oil to remove sulphur, during which time the sulphur combines with the lead, forming lead sulphide, which settles out. Color-makers' litharge is dissolved in diluted acetic acid to form soluble lead salts and these salts are used to produce the paint pigments, chrome yellow and chrome green.

Orange mineral is another lead compound identical in composition with red lead but rather paler in color, finer in texture, and lighter in weight. It is similar in character to red lead, too, has similar properties, and is used chiefly in the manufacture of vermilion paint, printing ink, and dipping paint. Its fineness, fluffiness, and high degree of oxidation make it valuable for these purposes.

Of all lead compounds, none is so universally used as white lead. In fact, nearly one-half of all the metallic lead produced in the United States enters into the manufacture of white lead and red lead. White lead is pure, refined metallic lead converted by a chemical process into basic lead carbonate. It is a chemical compound analyzing about 69 per cent carbonate of lead and 31 per cent hydrated oxide of lead.

White lead is of importance as a paint because of its opacity or hiding power, its preservative properties, and its durability. The hiding power is due not to the absorption of light but to the ability of the fine particles of white lead to refract or turn aside the light rays. This property of a substance to refract light rays can be observed, and the power of such refraction as compared to the similar power of some other substance taken as a standard, is designated the refractive index. Thus air, which transmits light practically without bending or refracting the rays at all, is taken as unity, and compared to air white lead has a refractive index of a little over two, which is higher than that of any white pigment in commercial use.

White lead, of course, is of no value as a paint unless incorporated in some vehicle, commonly an oil. The desirable feature of a paint oil is the ability to set up or dry in a short period to a hard surface

that will not take dust. This drying property is dependent upon the chemical nature of the oil; and if it is an unsaturated compound like linseed oil, rapid absorption of oxygen will cause the film to dry rapidly and become hard. A saturated oil like mineral oil will not take up oxygen to any great extent, and drying will therefore not take place. Linseed oil is the oil obtained by crushing the seed of the flax plant and because of its rapid drying properties and general adaptability for all classes of paints has never been supplanted by any other oil.

Many salts of lead other than the oxides are used, and for a variety of purposes. The most important of these are lead acetate, lead nitrate, and lead arsenate. Lead acetate, commonly known as sugar of lead, has certain medicinal values, especially in skin diseases. It is used also in textile dyeing and calico printing and in the manufacture of lead chromate or chrome yellow, a much-used pigment. Lead nitrate, too, is used in dyeing and in the manufacture of the paint pigments chrome yellow and chrome green. Lead arsenate is used largely as an insecticide, especially for the protection of fruit trees against the larvæ of the gypsy moth. Other commercially used lead salts are basic lead sulphate, basic lead chromate (a red pigment), and lead fluosilicate. Two grades of basic lead sulphate are in extensive use, namely, white and blue, the latter being essentially white basic lead sulphate colored with lampblack accidentally in the process of manufacture. They closely resemble white lead in appearance, but differ in certain physical characteristics as well as in chemical composition, the white analyzing about 80 per cent lead sulphate, 15 per cent lead oxide, and 5 per cent zinc oxide, and the blue analyzing lower in lead sulphate, higher in lead oxide, and from 2 to 3 per cent carbon. A large part of the production of the white sulphate is used in combination with some other white pigment for paint, and practically all of the remainder is used in the rubber industry for tubing, hose, automobile tires, and molded articles. The blue sulphate likewise is largely used in the manufacture of rubber products, and a portion is utilized for metal paint.

THE MANUFACTURE OF SHEET LEAD, PIPE, AND SHOT.

The manufacture of sheet lead involves the recasting of "pig" lead into flat plates and passing these through a series of rolls until the desired thickness of the sheet is attained.

Lead pipe is without seams, for it is made by forcing the semi-molten metal through a circular die.

Lead shot is made by alloying the metal with arsenic, which imparts a greater fluidity to the metal and increases its tendency to assume a spherical form. The molten metal is caused to run through collenders and to fall through a considerable height into water.

The height required is usually secured by means of a "shot tower"—a well-known edifice to the people of certain sections of the country.

THE MANUFACTURE OF WHITE LEAD.

White lead is made by corroding "pig" lead. Four processes are in practical commercial operation in the United States, but the greater bulk of the white lead is produced by a single one known as the "Old Dutch Process."

OLD DUTCH PROCESS.

To corrode lead by this process takes from 90 to 110 days. The practice is substantially as follows:

A layer of spent tanbark thoroughly wet down with water is spread about 20 inches thick on the floor of a bin or corroding compartment. Rows of earthenware pots shaped somewhat like flower-pots, about 12 inches high and 8 inches in diameter at the top and tapering to about 5 inches at the bottom, are placed thereon close together. In the bottom of each pot is poured about one-half pint of weak acetic acid (practically vinegar). The pots are then filled with wafflelike perforated disks or "buckles" of extremely pure lead previously cast from molten "pig" lead. Each buckle is about 6 inches in diameter and three-sixteenth of an inch thick. The buckles are piled flat and rest on a shoulder near the bottom of the pot which prevents the metal from coming into direct contact with the acid. From 10 to 14 buckles are put in each pot.

Over the filled pots is laid a floor of planks and on these planks is spread another layer of tanbark. A second layer of pots is then arranged as before, and alternating layers of pots and tanbark are built up until about 10 tiers, or a "stack," are in place.

Fermentation of the tanbark soon sets in. The heat thus generated, the temperature of which ranges between 160° and 180° F., causes the acetic acid to volatilize. Its fumes attack the lead, changing the metal on the surface to a thin film of acetate of lead. Carbonic acid gas, liberated by the decomposing tanbark, acts on this film of acetate of lead, converting it into carbonate of lead. The action of the carbonic acid gas on the acetate of lead frees acetic acid in the latter, and this freed acid attacks the metallic lead just below the first film of white lead and changes more lead to acetate of lead, which in turn is changed, by the process described, to carbonate of lead. Continuous attacks of acetic acid and carbonic-acid gas proceed in this way until all the lead clear down to the heart of the buckle is corroded into white lead.

At the end of about four months the stack is taken down or "stripped." The buckles of lead, which were blue, are found to be white except for a core of metallic lead which sometimes remains

in the imperfectly corroded buckles. This white material is hydrated carbonate of lead, or white lead. The pots are emptied, one by one, into a large container equipped with an exhaust fan, so that the dust created in the emptying is carried off and does not contaminate the air about the workmen.

From the stack the corroded buckles are conveyed to a separating machine. Here they are broken up by tumbling about in a revolving screen called a "buckle beater," and all uncorroded portions of lead are separated from the white lead.

The white lead is then mixed with water and ground again and again between heavy rapidly revolving millstones until it is fine enough to float on water through a long, oblong box called a "drag box." The coarse particles of white lead sink to the bottom of the drag box and are mechanically returned to the millstones for re-grinding.

The white lead that is fine enough to float through the drag box enters a series of four huge tubs in which the water is agitated constantly by revolving rakes. These tubs are known as "rake tubs." In the rake tubs, the white lead is washed free from traces of acid and other impurities; here also any coarse particles that accidentally passed the drag box settle to the bottom.

After floating through the series of rake tubs, the white lead (still floating in water) flows on to a screen of silk bolting cloth containing about 27,000 microscopic holes to the square inch. Only white lead which is fine enough to pass through these holes is used in paint, that which remains on the screen being rejected and reground. The white lead passing through the screen is pumped into large settling tubs where it settles to the bottom as wet pulp, the surplus water being drawn off from the top.

The wet pulp is then pumped upon a series of drying pans where the moisture in it is evaporated by means of steam surrounding the pans. (This operation requires periodical stirring of the pulp by hand and the series of pans is so arranged and connected with a revolving exhaust fan that when any door in front of a pan is opened a strong draft of air is drawn in and carries away any dust particles raised in the act of stirring.) From the drying pans the dried white lead is conveyed to mixers, known as "chasers," where it is mixed with linseed oil, then to stone mills, where it receives its final grinding, after which it is packed in appropriate containers. Eight pounds of linseed oil to ninety-two pounds of white lead is the usual mixture.

The other commercial methods of manufacturing white lead are known as quick processes because they lessen the time required to corrode the lead. The two most successful processes are the Carter and the Matheson, the principle underlying both being the same as

that on which the Old Dutch Process is based. In each instance the lead is first changed to acetate of lead and then converted into hydrated carbonate of lead.

The Carter process takes about 12 days to convert the lead into white lead. The rapidity of the process is due to the finely divided state of the metallic lead with which it starts. By this method granulated lead resembling gunpowder is sprayed with acetic acid in a great revolving wooden drum. As in the Old Dutch Process, the acid immediately attacks the lead, forming acetate of lead. Purified coal gas which contains carbonic acid gas is then introduced and changes the acetate of lead to white lead.

In the Matheson process the metallic lead is first "feathered," or made to resemble a sponge in structure, by running molten lead into water. It is then dissolved in acetic acid, and by contact with carbonic acid gas, precipitated in the form of a white powder which is hydrated carbonate of lead or white lead.

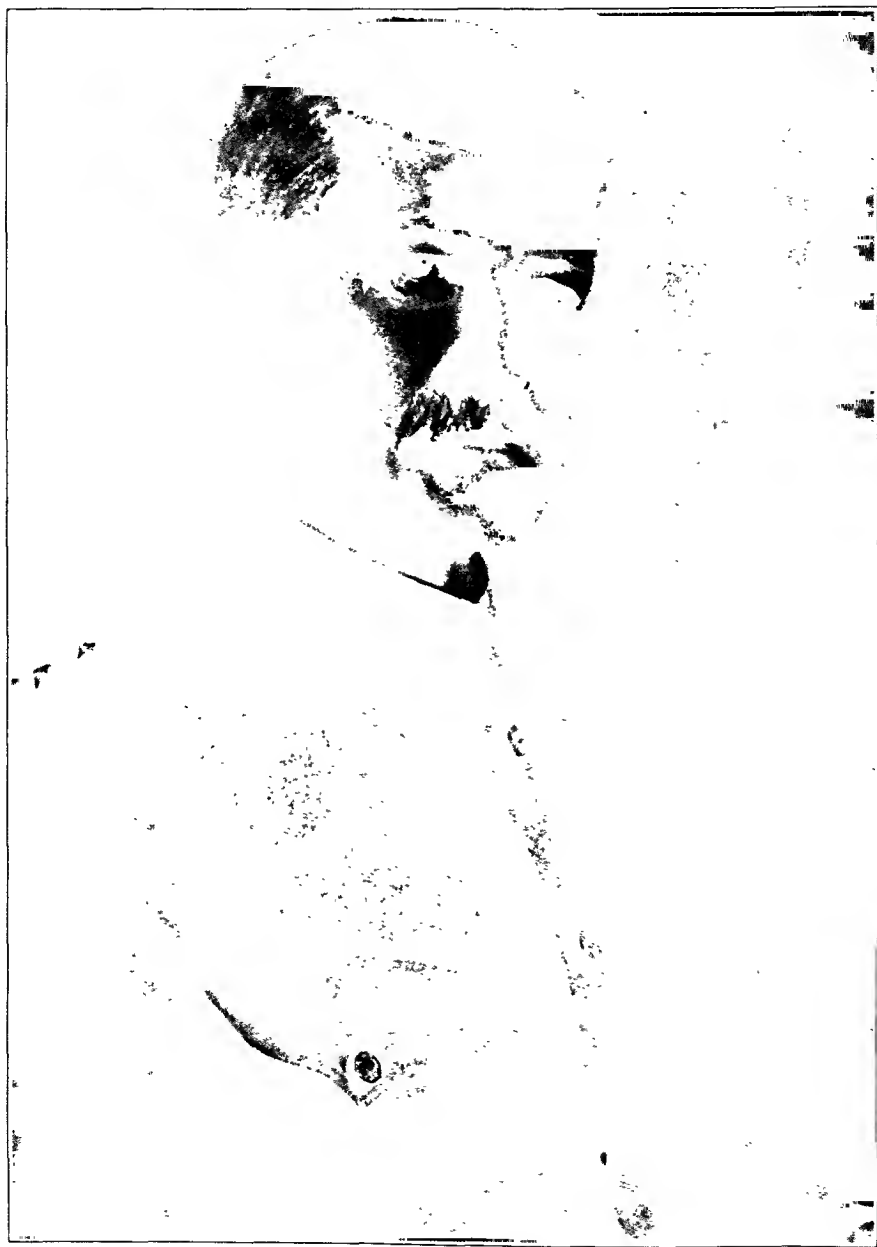
MANUFACTURE OF LITHARGE AND RED LEAD.

By far the greater proportion of litharge is made by calcining or roasting pig lead in specially constructed furnaces, called reverberatory furnaces, so named because the heat is reverberated or thrown down from an arched roof upon the material being treated. The hearth of the furnace is about 10 feet square and fireplaces are at opposite sides from which the flame is directed to the arch of the hearth. The arch is $2\frac{1}{2}$ to 3 feet above the hearth. The method of the manufacture of litharge is substantially as follows: About $1\frac{1}{2}$ to 2 tons of pig lead are placed in the furnace. At 620° F. the lead begins to melt but there is not much oxidation until the temperature is raised considerably, and it is often as high as $1,600^{\circ}$ before oxidation is complete. While the lead is molten, it is constantly stirred or "rabbled" with iron-handled rakes mechanically operated so that all parts of the lead are exposed to the oxidizing action of the air. Gradually the molten mass becomes granular, and with continued heat all of the lead is converted into oxide or litharge. The process requires from 24 to 36 hours, and in that time, with the temperature at from $1,100^{\circ}$ to $1,600^{\circ}$ F., the lead takes up all the oxygen that it will hold in its present condition. If the heat has been sufficiently intense to render the oxide pasty, it will, upon cooling, break down into small reddish-yellow flakes, known as flake litharge. The litharge as drawn from the furnace is then taken to a grinding mill where it is first pulverized, then floated on water so that any particles of metallic lead may settle out, and finally dried and packed. It is during the pulverization that the litharge assumes the buff color.

Red lead is made by heating litharge to a suitable temperature after the litharge has been cooled, ground, and purified. The heating is done in a reverberatory furnace where, at about 900° F., the buff-colored powdered litharge takes on more oxygen, changing in color to a brilliant red. This is red lead. The conversion takes about 48 hours. A peculiar phenomenon is that if the temperature is raised to 1,100° F. and higher, the red lead loses oxygen and reverts to litharge.

Orange mineral is made in the same way as red lead and litharge except that the process starts with white lead instead of pig lead. White lead is roasted in a furnace and turns to orange mineral as it takes in oxygen and releases carbon and hydrogen.

Basic lead sulphate is made from lead ore that contains zinc minerals in addition to galena. The process of manufacture consists in crushing, washing, and separating the minerals from associated rock by a gravity or "jigging" process, termed concentrating. The concentrates thus obtained are subjected to blast-furnace treatment in which volatilization takes place, and the volatilized portion of the concentrates are oxidized. The result is a white fume which is carried away by a draft of air and collected in bags. Blue basic lead sulphate is a by-product obtained in the above process. The lamp-black which colors it is an accidental ingredient resulting from incomplete combustion of carbon fuel used in the blast furnace.



WILLIAM CRAWFORD GORGAS.

WILLIAM CRAWFORD GORGAS.¹

By Brig. Gen. ROBERT E. NOBLE.

[With 1 plate.]

So much has been written about the life and work of Gen. William Crawford Gorgas, that whatever the writer may say will be much like repeating in new words facts that are already well known.

Intimacy with such a man does not always lead to ease in speaking or writing of his personality or of his work, for there may be feeling that represses rather than causes an easy flow of words.

Intimate association for more than 13 years, with this, the most knightly man that I have ever known, leaves me when I hear others speak of him, almost dumb. I listen, I think of him, of the great things he has accomplished and accomplished in the face of opposition and of a disbelief in him and in his methods, and finally of the acknowledgment by many of those who had opposed him that he was right, of the adoption of his methods by men and nations, of the lives he has saved, of the men yet unborn who because of his teachings will be conserved to the world, and finally of his end, while he was yet able to give to the world a service that would benefit mankind.

He was freeing the world from yellow fever, a disease that has taken its toll from both hemispheres, that has been epidemic for centuries in Central and South America and in the West Indies; a disease that has paralyzed commerce and has caused panic and disaster in the Southern States; a disease, which as a result of the practical application by General Gorgas of the discovery by the Reed Board that yellow fever is transmitted by a mosquito, and by only one mosquito, the *Stegomyia fasciata*, is now confined to a few endemic and epidemic centers, and which in five years will be eliminated from the earth.

General Gorgas was born at Mobile, Ala., October 3, 1854, the son of Gen. Josiah and Amelia Gayle Gorgas. He was educated in private schools until he entered the University of the South, graduating with an A. B. degree in 1875. Deciding to study medicine.

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he entered Bellevue Hospital Medical College, graduating in 1879. He served as interne, 1878-1880, and was commissioned as a first lieutenant and assistant surgeon in the Army, June 16, 1880. His first assignment to duty was at Fort Clark, Tex. In the fall of 1882 he was ordered to Fort Brown, Tex. Here he had his first professional experience with yellow fever, then epidemic on the Mexican border. This experience with this scourge so early in his career largely influenced his future. The mystery of its spread and its deadly nature appealed to his imagination, and he lost no opportunity to study this disease, and such opportunities were not infrequent for those who served at any of the stations located in the Gulf States, where yellow fever was from time to time epidemic. His cases were always carefully observed. Methods of treatment, hypotheses regarding the transmission of infection from man to man, and the various methods proposed for the control of epidemics, were studied and tested. All that he learned, or a supposition disproved, was a stimulus for greater effort. Further observation was temporarily interrupted in the fall of 1884 by reason of his transfer from Fort Brown to Fort Randall, Dak.

On June 16, 1885, he was promoted to the grade of captain and assistant surgeon. On Sept. 15, 1885, he married Miss Marie Cook Doughty of Cincinnati. Opportunity to resume the study of yellow fever came with his transfer to Fort Barrancas, Fla., where he served, with the exception of an 18-month tour of duty at Fort Reno, until the war with Spain. Shortly after the outbreak of the Spanish-American War he was appointed major and brigade surgeon. A vacancy in the regular service permitted of his promotion July 6, 1918, to the grade of major and surgeon in the regular establishment.

General Gorgas went to Siboney on the hospital ship *Relief*, and was present during the entire Santiago campaign. He established and was in command of the yellow-fever hospital at this place. He was invalided to the States after the occupation of Santiago, because of a severe malarial infection. After convalescence, he returned to Cuba, and was made health officer of Havana.

Here yellow fever was epidemic as it had been almost continuously since 1620. Havana was cleaned, one might say scrubbed and disinfected, but yellow fever remained. Case after case was found. No method tried served to lessen the incidence of the disease. The Reed Board was investigating theories advanced regarding the etiology of that disease. Their work was notable in proving that none of the etiological factors claimed by their sponsors was the true cause of the disease. The claim put forward by Dr. Carlos Finlay in 1881, that the *Stegomyia fasciata* was the agent by which the yellow-fever virus was transmitted from man to man alone remained. On Febru-

ary 6, 1901, in a paper read before the Pan-American Congress at Havana, a skeptical world was told that the theory of Finlay was a proven fact. There were many who questioned the findings of the Reed Board, but their experiment had been so carefully controlled and conducted with such mathematical precision that those who questioned succeeded in only confirming the accuracy of the findings. The elimination of yellow fever could now be undertaken on a definite basis, that of the control of *Stegomyia* breeding and reducing the *Stegomyia* index below a point capable of supporting an epidemic. Here was the opportunity that General Gorgas had been looking for, and hoping for, for years.

The eradication of the disease was simple in theory, but in reality, a task of magnitude. It meant house to house inspection, the location of all breeding places, the listing for future reference of all cisterns, tanks, wells, waterbarrels, fillers, water jars, in fact every container that would hold water and in which *Stegomyia* would breed. It meant the mosquito-proofing or the destruction of all possible breeding places. There were no trained inspectors for the work. They must be trained, while on the job. These inspectors were not kindly received; they were looked upon with suspicion, and their presence was resented. They had to fight ignorance and prejudice and meet the hostility of the householder with forbearance, tact, and judgment, a trying and thankless task.

The containers were found; the cisterns, tanks, wells, etc., either destroyed or made mosquito proof. Houses had to be fumigated to kill infected mosquitoes, for the *Stegomyia* is a long-lived insect and once infected is infectious to man for as long as she lives. The task was accomplished; yellow fever was eliminated from Havana. The last case was reported on September 28, 1901.

Malaria was a disease that also took a large toll from those living in certain sections of Havana. The fact recently proven that certain of the *Anopheles* mosquitoes were responsible for the transmission of the malarial parasite from man to man was utilized. So hand in hand with the elimination of yellow fever from Havana went the reduction in the incidence of malaria. The measures against *Anopheles* finally reduced the malarial index to an almost negligible quality, and made healthful areas of what for generations had been uninhabitable.

The work of General Gorgas at Havana was so notable that Congress showed the appreciation of the whole country, when on March 9, 1903, an act was passed promoting him to be a colonel and Assistant Surgeon General. Having completed his work in Havana he was assigned to duty as chief surgeon of the Department of the East, with station at Governors Island, and remained there until he was appointed chief sanitary officer of the Panama Canal by President

Roosevelt, March 1, 1904. Here was a task worthy of the man and a man equal to the task.

There were many natural difficulties to overcome, and much opposition both active and passive to meet. There was disbelief in the fact that yellow fever and malaria were transmitted by mosquitoes. This resulted in disbelief in the man and in his methods. In those early days a man less determined would have been not only discouraged but dismayed. His removal was desired; his recommendations held up and criticized, even characterized as "wild." All this did not hasten the accomplishment of the task but rather delayed it. The vicissitudes of the department of sanitation during this period are a matter of history as any one interested may see by reading the "Report to the Government, by Dr. Chas. A. L. Reed. Showing how the Commission makes Efficient Sanitation Impossible," published in the *Journal of the American Medical Association*, March 11, 1905, page 812; also the "Reply of the Commission to the charges made in the Report to the Government by Dr. Chas. A. L. Reed," published in the same *Journal*, April 1, 1905, page 1052. The fact remains that after this report matters affecting sanitation received more consideration, and recommendations were more promptly acted upon than previously. President Roosevelt with his usual keen understanding of men and methods was the force that upheld General Gorgas during those trying days and made success possible.

Malaria, yellow fever, and dysentery, were the three diseases that caused the greatest morbidity and mortality among employees of the French Canal Co. and the natives on the Isthmus. The climate was considered deadly, the whole region had a most sinister reputation. The "Forty-niners" crossing the Isthmus had died in great numbers. Fevers and dysentery during the period of the construction of the Panama Railroad had taken an enormous toll from the forces employed. It has been stated that each cross tie represented a life sacrificed in the construction of the railroad. One town on the line of the canal was said to have derived its name, Matachin, because of the awful mortality of the Chinese laborers quartered there. Neither of the statements are strictly true; they are quoted for the purpose of emphasizing the awful unhealthfulness and evil reputation of the Canal Zone and the cities of Panama and Colon, the regions that must be made healthful.

The death rate of the employees of the French Canal Co. has never been known with any degree of accuracy, all statistics being based on the deaths that occurred in hospitals only. The hospitals received patients sent in by contractors or the individuals who entered on their own responsibility. Under the French there was no free general hospitalization of employees as during the construction of the

canal by the United States. Because of this lack of general hospitalization, deaths occurring on the line of the canal and in the cities of Panama and Colon never appeared in the statistical tables of the French company. The hospital rate of 65 per 1,000 per annum is given as the rate of deaths for employees of the French company, and it is on this basis that all comparison of French and American statistics are based. The French rate of 65 per 1,000 per annum was high enough to be embarrassing, but a competent observer who lived in Panama during the days of construction by the French and who was in a position that gave him an intimate knowledge of actual conditions told General Gorgas that the French losses were not less than 250 per 1,000 per annum. Allowing that a death rate of 250 per 1,000 per annum is too high, the rate of 65 per 1,000 is undoubtedly too low. The true rate will never be known. It was so high, however, that only by great effort was it possible to keep the working force recruited up to a point of efficiency, that is, to obtain the average output with the equipment provided.

Many instances are recorded of the almost extinction of groups of employees arriving from France, who, being assigned to various stations, took up their work with enthusiasm in the expectation of great accomplishments, but within two or three months 75 per cent would have died, and in some cases even 100 per cent. The death rate among the Catholic sisters who controlled the hospitals was appalling. Travelers crossing the Isthmus did so at great risk, especially those who from necessity spent the night in either Panama or Colon.

The problem was to make this pest-ridden country a place where men could live at least in comparative safety, especially men from a temperate climate. In fact, it was more than this, for in order that these men might be contented and efficient, it was deemed advisable that they should bring their families. If the Canal Zone and the cities of Panama and Colon could not be made healthful to a degree that it would be possible for Americans to live there, the project would have been handicapped by great mortality and increased cost in time and money. Without proper sanitation the great sacrifice of lives would have had its reaction on public sentiment, making probable again the abandonment of the project.

It is estimated that had French conditions persisted instead of those established by General Gorgas the cost in human lives would have been not less than 20,000.

Those who opposed General Gorgas most strenuously during the early days of his work on the Zone from an honest disbelief in his methods, methods based on the transmission of yellow fever and malaria by mosquitoes, later acknowledged their error. I heard one

former official say to General Gorgas that they had been wrong, and that had their action resulted in his removal, as they desired, a great calamity would have resulted.

Statistics are as a rule uninteresting, but no one can fail to feel a real interest in the statistical tables published by the department of sanitation, Isthmian Canal Commission. These statistics tell the story of a lessening number of deaths, the story of a decreasing sick rate, and fewer days spent in hospitals, all this with an increasing population—a saving that paid, and more than paid, for all the moneys charged against the department of sanitation. The cost of sanitation has been criticized, but no attention has been paid the credit side of the ledger. Is it not proper to credit sanitation with the lessened sick rate and the lives saved? Divide the cost of sanitation by the one item of lives saved; the answer will be an answer to critics. There are other credits that may be considered that directly and indirectly bring their return to the United States. What of the great object lesson in sanitation—a lesson learned by the rest of the world? Other countries applied the methods practiced by General Gorgas. Especially did South America begin to "clean up."

Sanitation, the same as that practiced in Cuba and on the Canal Zone, freed some of the greatest ports of South America from yellow fever and reduced the incidence of malaria; it made travel safe; it lessened quarantine restrictions, and in some instances caused the entire removal of all quarantine, results that were of great benefit to trade.

General Gorgas taught the world that the Tropics were not of necessity the deadly region they had always been considered; that with proper methods those diseases, fatal to the native as well as the man from the temperate climate, could be eliminated, and once eliminated, they would not reoccur unless imported from some infected area. This fact forced unprogressive countries to improve sanitary conditions, to oust yellow fever and malaria. For if those countries wished to keep up with the commercial development of the world and obtain their fair share of the world trade, they must control communicable disease, if not with the view of conserving life, then from the viewpoint of commerce.

The first three years of General Gorgas's work on the Canal Zone as chief sanitary officer was in a subordinate capacity. The department of sanitation was not an independent department, but merely a branch of the department of government and sanitation. On March 1, 1907, President Roosevelt appointed General Gorgas a member of the Isthmian Canal Commission and head of the department of sanitation. This was a recognition of results accomplished, a triumph of the man and of his methods. So conspicuous was General

Gorgas's success in converting the Canal Zone and the cities of Panama and Colon into a region where the death rate was comparable to that of our healthiest cities that sanitarians came from all over the world to see and learn, and return to their homes with valuable data and new ideas. So impressive were his results that he received many invitations to advise corporations and countries on matters of health and sanitation. Two were accepted. The first was an invitation from the President of Ecuador to study the health conditions of Guayaquil and submit outline plans for the sanitary reconstruction of that city, the principal seaport of the Republic. Almost two months were spent in Ecuador, during which time tentative plans were prepared and recommendations submitted. The plans provided for adequate water supply, sewer system, paving the streets, modification of health laws, and the revision of building regulations, with especial reference to "rat proofing." His general plan was adopted and much work has been done. Guayaquil has for almost two years been free from yellow fever, and malaria incidence has been much reduced. At the time of General Gorgas's visit to Ecuador the death rate for Guayaquil was such that the city of almost 90,000 people must be repopulated each 15 years or cease to exist. The result of his visit is that one of the most unhealthy cities of the world is now a city with a death rate comparable to that of other tropical cities of the same size.

In the summer of 1913 Mr. Samuel Evans, chairman of the Chamber of Mines, Johannesburg, Transvaal, visited the Canal Zone to make inquiry in regard to the housing conditions of the laborers and the methods used for the control of pneumonia, a disease at one time epidemic among employees of the Panama Canal. The control of pneumonia was a matter of great importance to the mine owners of South Africa, as the native laborer was very susceptible to that disease, especially the tropical native. Among this class of laborers pneumonia was very fatal; in fact, so high had been the death rate from this cause that the bureau of native affairs had prohibited the employment in the mines of natives from tropical Africa. This closed a source that supplied each year about 20,000 laborers. A further restriction of recruiting areas was possible if the incidence of pneumonia could not be lowered. This was a very serious matter, for the mines required over 200,000 laborers on the rolls to keep up the average output. As a result of Mr. Evans's visit to the Canal Zone, the Chamber of Mines invited General Gorgas to visit the Rand and investigate conditions with the view of applying the methods that had been so successful on the Canal Zone. The invitation was accepted. General Gorgas sailed from Colon early in October, 1913, for South Africa, and arrived at Johannesburg in November. A preliminary survey of conditions was made. It was soon found that

this study would be very much more comprehensive than anticipated, for not only must pneumonia be investigated but housing, hospitalization, food, tuberculosis, method of recruiting, transportation of recruited laborers to the mines, and their repatriation on completion of contract. About three months were spent on this work. A report was submitted and discussed with the Chamber of Mines in open session. Some of the mines that had sufficient "life" to warrant it adopted General Gorgas's plan. One group of mines employed at General Gorgas's suggestion a sanitarian, who was given charge of all matters pertaining to health and sanitation. The result justified expectations.

While at Johannesburg, General Gorgas was invited by the Governor of Rhodesia to come to Salisbury, the capital, to give advice as to the control of malaria and discuss the question of black-water fever, the cause of great morbidity and considerable mortality among the European settlers of Rhodesia. Many farms and a few small settlements were visited, much advice given, several public meetings held, as well as conferences with the colonial health officers and civilian practitioners. All were eager for information and advice.

While at Salisbury, General Gorgas dined one evening with the governor. When General Gorgas entered the drawing room the governor advanced and said, "I am glad to see you, General Gorgas." After greeting the governor, General Gorgas said, "You are mistaken; I am a colonel." The Governor said, "It is you who are mistaken—you were made a general yesterday." With this he gave to General Gorgas a news bulletin, announcing his appointment as Surgeon General of the Army, with the rank of brigadier general.

On completion of the work at Rhodesia, General Gorgas returned to Johannesburg, finished his work on the Rand, and in February sailed from Cape Town for the United States, via England. He arrived in New York the last of March, proceeded to Washington, and assumed the duties of Surgeon General of the Army.

His policies on assuming this office were to improve sanitary conditions, build up a reserve of hospital supplies equal to that recommended by the Dodge Commission; reorganize the Medical Reserve Corps, increasing its commissioned personnel to such a point that it would meet the demands of war, to reorganize the Medical Corps upon a basis that had a definite relation to the strength of the Army. These various projects were in process of accomplishment when we entered the World War. The Medical Corps had been reorganized, reserve supplies were in process of accumulation, and there were sufficient officers in the Medical Reserve Corps to meet the first demands of the new Army.

On March 4, 1915, he was made a major general and received the thanks of Congress for service as chief sanitary officer of the Panama Canal.

When the war was declared by the United States against Germany, there were but five officers, including General Gorgas, on duty in the office of the Surgeon General and about 85 clerks. The force was expanded to more than 200 officers and 1,800 clerks. The department twice outgrew the quarters assigned and was obliged to move. These moves were accomplished without confusion and with but little delay in the routine of the department.

During the war all demands were met, all requisitions filled, a gigantic task accomplished with the minimum delays and maximum efficiency. General Gorgas went to France in the fall of 1918, was present at the battle of St. Mihiel, visited other battle fields, and inspected hospitals and sanitary arrangements of the American Expeditionary Forces.

He was retired on October 3, 1918, having reached the statutory age limit.

He then associated himself with the International Health Board of the Rockefeller Foundation, of which he was a permanent director. With the board he was director of the yellow fever commission. He spent the greater part of his time in Central and South America, fighting for the elimination from the world of this disease, the accomplishment of which is in sight, there being at this time but few centers where the disease is either endemic or epidemic. On May 8 last General Gorgas sailed from Quebec for England and Belgium, intending in June to go to the West Coast of Africa to investigate past epidemics of yellow fever and to study such cases as might be present at the time of his visit.

He was in Belgium from May 20 to 29 for the purpose of interviewing the Belgian authorities about his proposed visit to the Belgian Congo. He also had an audience with the King of the Belgians, who takes a keen interest in all matters pertaining to health, and especially to tropical sanitation.

During this time the Royal Institute of Public Health (British) was in session, and the institute at this meeting bestowed upon General Gorgas the Harbin medal, awarded for achievements in public health. He returned to England on May 29. On the morning of the 31st began his last illness. He was a patient in the Queen Alexandra Nursing Home for Superior Officers. While sick in hospital he was visited by the King, who invested him with the Cross and Star of Knight Commander of the Order of St. Michael and St. George.

General Gorgas died at 1.35 a. m., July 4, 1920.

The Royal Society of Medicine planned a funeral service at St. Paul's, but the British Government determined upon a State funeral. On the morning of July 9 the British Government paid its tribute to the man. The honors paid him in death were worthy of the great benefits he had bestowed upon the world, and of the life he had lived.

With many, "the good is oft interred with their bones." A few men are for their works blessed by their contemporaries; others are remembered by posterity. Seldom does that man live whose works are blessed by his contemporaries and whose memory will be held in reverence by future generations. General Gorgas was such a man. A great man has gone; there is no one upon whom his mantle can fall.

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